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RADIANT HEATING AND COOLING

What It Is
How It Is Figured
Examples of Its Successful Installation

A reproduction of articles originally published in the Journal HEATING, PIPING AND AIR CONDITIONING

Issued by
KEENEY PUBLISHING COMPANY
6 North Michigan Avenue, Chicago, Illinois

Radiant Heating and Cooling

What It Is and How It Is Figured

By F. E. Giesecke*

HEAT may be conveyed by conduction, by convection or by radiation. In the present state of the art of heating and cooling buildings, the transfer of heat is most commonly effected by convection, to a lesser extent by radiation, and least by conduction. However, in every heating or cooling installation, all three methods of heat transfer are present.

If a room is heated by means of a free-standing radiator filled with steam or hot water the heat transfer from the radiator to the room is about 30 per cent by radiation and about 70 per cent by convection. If a room is heated by means of warm air, the heating is effected almost exclusively by convection. However, in this case, the ceiling and one or more of the walls are warmer than other parts of the room and its contents and they dissipate their excess heat by radiation. The only case in which heat is transmitted purely by radiation is that in which the radiant energy passes through a vacuum. For example, the flow of heat from the sun to the earth is purely by radiation.

Before discussing radiant heating and cooling in detail, it is important to develop a clear understanding of the nature of *heat* and of *radiant heat,* so-called.

Heat Is Kinetic Energy of Molecules

If two iron bars (Fig. 1) are exactly alike except that one is warmer than the other, the difference between them is that the molecules in the warmer bar move with a higher mean velocity than those of the cooler bar.

It is difficult to realize that an iron bar is not a single rigid body but that it is an aggregation of an exceedingly large number of exceedingly small molecules which are so close together that they cohere with great tenacity and yet are far enough apart so that they are in continuous motion so long as the iron bar has a temperature above —460, the absolute zero of the Fahrenheit temperature scale.

In the case of liquids and gases, it is easier for us to realize that they are aggregates of molecules because one is familiar with the phenomenon of evaporating water, i.e., of transforming water into steam simply by increasing the distances between molecules. If 1 cu ft of water is evaporated at ordinary temperatures and pressures, about 1600 cu ft of steam is formed. If one assumes that the molecules in the steam are of the same size as those in the water and that the molecules in water are practically in contact with each other, it follows that the distance between centers of molecules in the steam must be about 12 molecule-diameters (Fig. 2) because the cube root of 1600 is about 12. At like temperatures and pressures, all gases have the same number of molecules in a given volume. The molecules in ordinary saturated air may, therefore, be represented as shown in Fig. 2.

The size of the oxygen molecule is about 1 in. divided by 125,000,000. Its mean velocity is about 1500 feet per second. Since all molecules in a given gas have the same kinetic energy, the mean velocities of the nitrogen and the water molecule are about 1600 and 2000 fps, respectively, when that of the oxygen molecule is about 1500, because their masses are correspondingly smaller than that of oxygen.

In the preceding discussions, molecules were referred to as if they were spherical bodies. This is not the case. A molecule is composed of atoms which move

Summary of
Radiant Heating and Cooling

By F. E. Giesecke

Before discussing radiant heating and cooling in detail, it is important to develop a clear understanding of the nature of heat and of so-called radiant heat. Heat is the kinetic energy of molecules, the difference between, say, a warm iron bar and a cold iron bar being only that the molecules in the warm bar are moving with a higher mean velocity than are those in the cooler bar. One result of the complicated molecular, atomic and electronic motions in a body is that energy is continuously radiated from the surfaces of all bodies whose temperatures are higher than absolute zero (—460 F). Radiant energy having a wave length from about 4000 to 400,000 angstroms (an angstrom being one meter divided by 10,000,000,000) is known as radiant heat because when it impinges on a body it increases the kinetic energy of the molecules of the body and therefore its heat content and temperature. Radiant heat is that radiant energy which is partially transformed into heat when it is intercepted by a body. . . . . The rate at which a perfect radiator (black body) radiates energy is $Q = 0.174 (T/100)^4$, where Q is Btu per sq ft per hr and T is absolute temperature, or degrees Fahrenheit plus 460. It is sufficiently accurate to use a constant of 0.156 for materials used in building construction, in place of 0.174 as given in the preceding equation. Heat transferred by radiation from a warmer to a cooler surface thus may be calculated by the equation $Q = 0.156 [(T_1/100)^4 - (T_2/100)^4]$. . . . .If the temperatures of the surfaces in a room are not equal to each other, but differ only slightly, the mean radiant temperature may be calculated by multiplying the area of each surface by its temperature and dividing the sum of the resulting products by the sum of the surface areas—the quotient is the *mean radiant temperature.* . . . . When a room is heated by means of a warm ceiling, air convection currents are produced which transmit additional heat from the ceiling. To calculate this quantity of heat it is necessary to know the film coefficient for transfer of heat from the ceiling to the air; for a ceiling it is probably less than the Guide figure of 1.65 for interior walls—possibly 1.0. Accurate calculations of this part of the problem can only be made after reliable data are available from carefully conducted research; at present, it seems to be sufficiently accurate to assume the heat transmitted from the ceiling by convection to be about 50 per cent of that by radiation

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Fig. 1

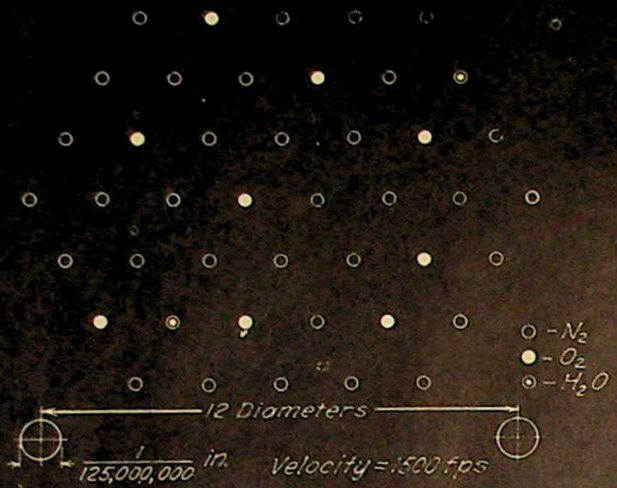
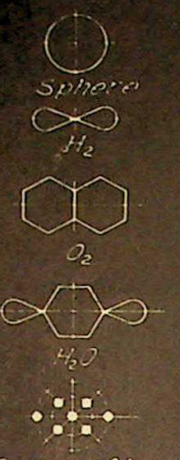


Fig. 2



Oxygen Atom

Fig. 3

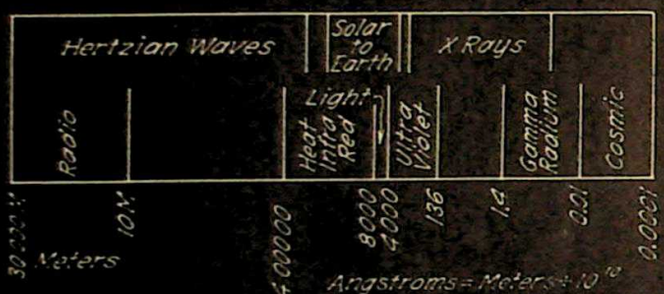


Fig. 4

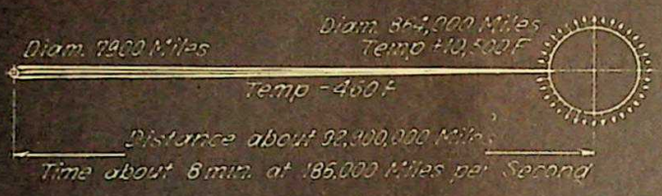

Diam. 7900 Miles
Diam. 864,000 Miles
Temp +10,500 F
Temp -460 F
Distance about 92,900,000 Miles
Time about 8 min. at 186,000 Miles per Second

Fig. 5

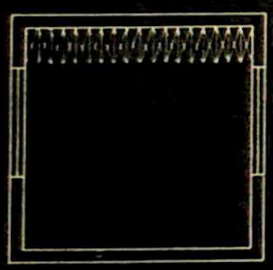


Fig. 6

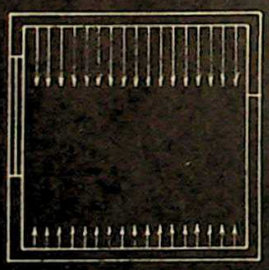


Fig. 7

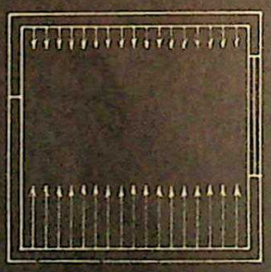


Fig. 8

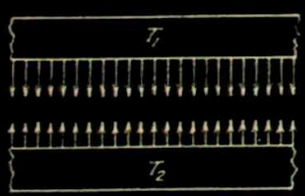


Fig. 9

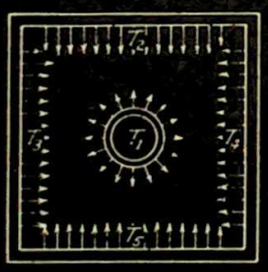


Fig. 10

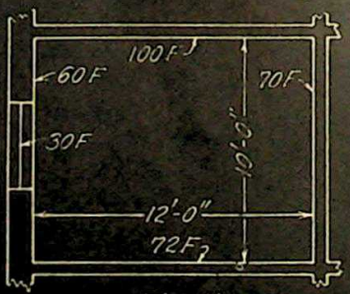
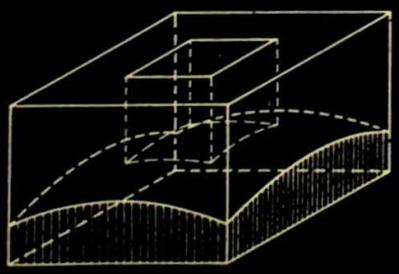


Fig. 11



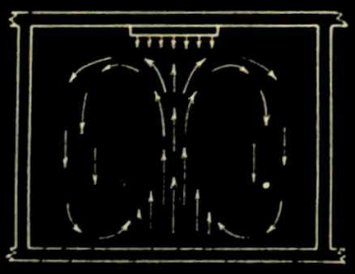


Fig. 12

about within the molecule. The atom has a very complicated structure, as indicated in Fig. 3; it consists of a central body surrounded by electrons which move about within the atom.

One result of these complicated motions (or some of them)—molecular, atomic, and electronic—is that energy is continuously radiated from the surfaces of all bodies whose temperatures are higher than — 460 F. The nature of this radiant energy is not definitely understood. It is believed that the energy is radiated in pulsating discharges of small units called *quanta* or *corpuscles*. The effect of the pulsating discharges is the same as that of wave motion; the corresponding waves are electro-magnetic waves. It is known that the energy is radiated from every point of every surface, in all directions, in straight lines, and at a very high velocity—about 186,000 miles per second. It is also known that the intensity of the radiant energy varies with the character of the surface from which it is radiated, that it is proportional to the fourth power of the absolute temperature of that surface, that its intensity varies inversely as the square of the distance from the source, and that it is propagated in waves of widely varying lengths (Fig. 4). The longer waves are measured in meters; the shorter waves in *angstroms*. An angstrom is one meter divided by 10^{10} or by 10,000,000,000.

Radiant energy of the longer wave lengths is used for radio transmission and that of shorter wave lengths for x-ray work. Radiant energy having a wave length of from 8000 to 4000 angstroms is that peculiar type which can be sensed by the human eye—light—and which gives the human mind the sensation of color—red, yellow, blue, and their innumerable gradations. Radiant energy having a wave length of from about 4000 to about 400,000 angstroms, with the maximum effect at about 20,000, is known as *radiant heat*, because when this radiation impinges on a body it accelerates the molecular motion in that body, i.e., it increases the kinetic energy of the molecules and therefore the heat content and temperature of the body. In other words, *radiant heat is that type of radiant energy which is partially transformed into heat when it is intercepted by a body.*

Fig. 1—Two iron bars exactly alike except that one is warmer than the other. The only difference between them is that the molecules in the warmer bar move with a higher mean velocity than those of the cooler bar. . . . Fig. 2—The molecules in saturated air. . . . Fig. 3—Diagrammatic representation of the atoms in hydrogen, oxygen, and water molecules and of the structure of an oxygen atom. . . . Fig. 4—The varying wave lengths of radiated energy. . . . Fig. 5—The sun, the most important radiator for mankind. . . . Fig. 6—Energy radiated in all directions from every point in the ceiling (also from every point in the floor and walls). . . . Fig. 7—The ceiling functioning as the heating element or radiator for the room. . . . Fig. 8—The ceiling functioning as the cooling element or refrigerator for the room. . . . Fig. 9—The transfer of radiated energy between two large and parallel surfaces, near each other, and at different temperatures. . . . Fig. 10—The transfer of radiated energy when one radiating surface is entirely surrounded or enclosed by the other. . . . Fig. 11—A room 12 ft by 15 ft by 10 ft high. Ceiling temperature is 100 F. Mean radiant temperature of remaining five surfaces (floor and four walls) is 67.6 F. . . . Fig. 12—Temperature distribution over the floor of a room heated by a panel in the ceiling and the air currents which are produced thereby

Amount of Heat Radiated

When radiant energy impinges on a body a part of the energy is reflected, a part is absorbed, and a part passes through the body. The rate at which a body absorbs the radiation which impinges on it is proportional to the rate at which that body radiates energy. If a body absorbs all radiant energy which impinges on it, it is a *perfect absorber*. Such a body is also a *perfect radiator*. There is no perfect radiator in nature. A body with a rough surface coated with lamp black is almost a perfect radiator and, for that reason, a perfect radiator is called a *black body* and its radiation is called *black radiation*. All other radiation is called *gray radiation*. The rate at which a perfect radiator (black body) radiates energy is

$$Q = 0.174 \times \left(\frac{T}{100}\right)^4 \quad [1]$$

where Q = Btu per sq ft per hr and T = absolute temperature = degrees Fahrenheit plus 460.

If such a body has a temperature of 100 F (560 T) it will radiate energy at the rate of $0.174\ (5.60)^4$ or 171 Btu per sq ft per hr. The radiation factors of some of the materials commonly used in building construction, which should be employed in place of the constant 0.174 in Equation 1, are:

Brick	0.162	Glass	0.156	Paper	0.162
Cast iron	0.150	Linoleum	0.154	Stone	0.147
Cloth	0.136	Mortar	0.158	Wood	0.158

Since the data for heating and cooling calculations are generally quite variable, it is not necessary to use extreme refinement in such calculations and it is sufficiently accurate to use a common radiation factor of 0.156 for stone, brick, mortar, plaster, wood, linoleum and other similar materials used in building construction.

The one radiator of greatest importance to mankind is our sun (Fig. 5). The sun radiates energy in all directions. A very small portion reaches our earth; after having passed through about 93,000,000 miles of space, which has a temperature of — 460 F, it delivers heat to the earth at a rate of about 360 Btu per sq ft per hr on a surface at right angles to the sun's rays. A part of the sun's energy is absorbed by the molecules of the air and by the dust particles in the air; the remainder reaches the earth. The radiation coming to the earth from the sun varies in wave length over a range which includes light radiation and heat radiation and extends somewhat on either side of those two groups.

Just as every point in the surface of the sun radiates energy, so do all points in the surfaces of the floor, walls, and ceiling of our buildings (Fig. 6). If the temperature of the ceiling of a room is higher than the mean temperature of the floor and walls, the ceiling will be a heating surface for the room (Fig. 7) but if the temperature of the ceiling is lower than the mean temperature of the floor and walls, the ceiling will be a cooling surface for the room (Fig. 8).

Advantages of Panel Warming

The method of heating buildings by means of warm panels in the ceilings, floors or walls is called *panel warming* or *radiant heating*.

The following advantages are claimed for the panel warming system by its advocates—

1) The radiators are out of sight and do not occupy floor space which can be used for other purposes.

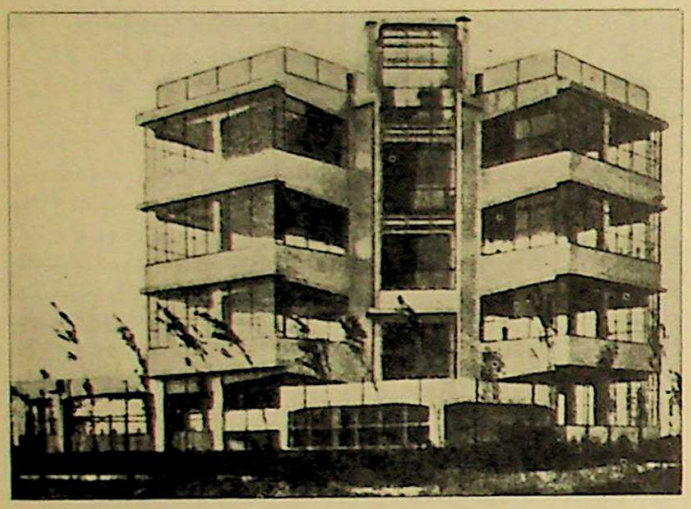
2) When the structural frame of a building has been completed, the heating system has also been completed and heating can be begun immediately to facilitate completion of interior work.

3) The heating system does not affect the location of partition walls or later changes of such walls.

4) When used in prisons or asylums, the system cannot be tampered with by the inmates.

5) The system can be used for cooling as well as for heating in those localities where the humidity is not too high.

6) The floors are warmer than in buildings heated by more ordinary systems and cold air currents along the floors are less intense.



Open air school in Amsterdam heated by radiant type system

7) Air currents within the room are materially reduced so that dust particles, to which disease producing organisms may be attached, can settle out, thereby producing a purer and more sanitary air within the building.

8) The first cost of the system depends largely on labor costs and will not vary much from that of the ordinary heating systems.

9) The cost of operating the system is somewhat lower than that of the ordinary system for the following reasons: (a) For equal comfort, the temperature of the air within the building is slightly lower and hence the cost of heating the air which passes through the building is lower; (b) the heat loss through outside walls is somewhat lower, especially when the windows have double glazing; (c) when either water or air is used as the heating medium, lower temperatures are used than in ordinary heating systems and therefore an economy in fuel combustion can be effected.

In radiant heating systems the heating panel may be situated entirely or partly on the ceiling, floor or walls. The heating medium may be water, steam, air or electricity.

In radiant cooling systems, the cooling panel should be situated in the ceiling except in operating rooms where panels should be in the walls and ceiling; cooling panels in the ceiling effect a general cooling of the entire room and those in the wall affect primarily the operating surgeon and his assistants. The cooling medium may be water or air.

Fundamentals of Design

Before undertaking the design of a radiant heating or cooling system, the following fundamentals should be considered: When two plane surfaces (Fig. 9) of considerable size are parallel and near each other and maintained at different absolute temperatures, T_1 and T_2, the heat transferred by radiation from the warmer to the cooler surface may be calculated by the equation

$$Q = 0.156 \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right] \quad [2]$$

because the energy radiated by either surface may be calculated by Equation 1. For example if the temperatures of the two surfaces are 120 F and 70 F, respectively, the flow of heat by radiation from the warmer to the cooler surface will be at the rate of about 53 Btu per sq ft per hr.

If the two surfaces shown in Fig. 9 represent the ceiling and the floor of a room, Equation 2 cannot be used to calculate the transfer of heat by radiation from one to the other (except very approximately), especially if the room is small and the ceiling high, because a large part of the energy radiated by the floor and by the ceiling is radiated to the walls, and the remainder only goes to the ceiling or floor.

However, when one surface is entirely enclosed by another surface (for example Fig. 10, where a horizontal steam pipe is used to heat a room) the heat transmitted by radiation from the steam pipe to the walls, floor, and ceiling can be calculated accurately by Equation 2 if the temperatures T_2, T_3, T_4 and T_5 of the ceiling, walls, and floor are all equal.

If these temperatures are not equal, and do not differ materially from each other, it is sufficiently accurate to use their *mean value,* which is calculated by multiplying the area of each surface by its temperature and then dividing the sum of the resulting products by the sum of the surface areas. The resulting quotient is the mean temperature and is called the *mean radiant temperature* of the room. For example, if a 2 in. steam pipe is used to heat a room when the mean radiant temperature of the room is 70 F and the temperature of the pipe is 220 F, heat will be transferred from the pipe to the room by radiation at the rate of about 210 Btu per sq ft per hr. However, convection currents will be set up which transfer additional heat from the pipe to the room at the rate of about 190 Btu per sq ft per hr. (See The Cooling of Water in Iron Pipes, by F. E. Giesecke, HEATING, PIPING AND AIR CONDITIONING, August, 1929, pp. 267-272).

If the temperatures of one or more of the surfaces differ materially from the remaining temperatures, the *MRT* should be calculated by multiplying the several areas by the fourth power of their respective absolute temperatures and dividing the sum of the products by the sum of the areas; the fourth root will be the required absolute temperature.

When the ceiling is used as the heating surface of a room, one may assume that the surface of the ceiling is entirely enclosed by the surfaces of the walls and floor, and one can then calculate with sufficient accuracy by means of Equation 2 the heat transferred by radiation to the room from the ceiling, by using the ceiling surface temperature as T_1 and the mean radiant temperature of floor and walls as T_2.

For example (Fig. 11) the assumed surface temperatures are ceiling 100 F, floor 72 F, inside walls 70 F, outside wall 60 F, glass 30 F. The floor area is 180 sq ft; the inside wall areas are 150, 120, and 120 sq ft; the outside wall area is 150 sq ft (including glass); and the glass area is 20 sq ft. The ceiling area is of course 180 sq ft. The mean radiant temperature of the floor and walls therefore is $[72 \times 180 + 70\ (150 + 120 + 120) + 60\ (150 - 20) + 30 \times 20] \div 720$ or 67.6.

The heat transmitted *by radiation* from the ceiling to the room is then

$$Q = 180 \times 0.156\left[\left(\frac{560}{100}\right)^4 - \left(\frac{527.6}{100}\right)^4\right] = 5860 \text{ Btu per hr}$$

Convection Currents

When a room like that shown in Fig. 11 is heated by means of a warm ceiling, air convection currents are produced within the room which transmit additional heat from the ceiling to the room as one can readily see from Fig. 12 and from the following explanation: Since every point of the ceiling radiates energy, and since the intensity of this radiation varies inversely as the square of the distance, it is evident that the corners of the floor receive the least, and the center of the floor the largest, quantity of energy—and that therefore the floor is warmest in the center and coolest at the corners and that the temperature of the floor varies somewhat as the ordinates of the double curved surface sketched in on Fig. 12. As a result of this temperature variation, a current of warm air will rise from the center of the floor to the ceiling, spread along the ceiling in all directions to the walls—especially toward the outside wall—and return downward along the walls and in so doing convey heat from the ceiling to the walls and the room contents.

To calculate the quantity of heat conveyed by this flow of air, it is necessary to know the film coefficient for the transfer of heat from the ceiling to the air and also the average temperature of the blanket of air in contact with the ceiling. The Heating, Ventilating, Air Conditioning Guide (published by the American Society of Heating and Ventilating Engineers) recommends a value of 1.65 for interior walls. For the ceiling it is probably less, possibly 1.0. The average temperature of the air in contact with the ceiling may be assumed to be 85 F. Using these values, one finds

$$Q = 180 \times 1.0\ (100 - 85), \text{ or } 2700 \text{ Btu per hr}$$

This calculation may be quite inaccurate because it is based on an assumed value of the film coefficient and also on an assumed value of the average temperature of the air in contact with the ceiling. It is given here primarily to indicate the procedure in such a calculation. Accurate calculations can be made only after reliable data are available from carefully conducted research. . For the time being, it seems sufficiently accurate to assume that the heat transmitted from the ceiling by convection currents is equal to 50 per cent of that transmitted by radiation. In that event, the heat transmitted from the ceiling to the room shown in Fig. 11 is 5860 + 2930 or 8790 Btu per hr. If the heat loss of the room is less than 8790 Btu, it is necessary either to reduce the temperature of the ceiling below 100 F or to let the heating panel extend over only part of the ceiling.

Radiant Heating and Cooling

F. E. Giesecke* Explains Fundamentals of Design for a Type of System Which Is Attracting Wide Interest

SUMMARY

Just as the warm ceiling in a room radiates energy in all directions, so do the walls and floor, the intensities of the radiations from the various surfaces varying directly as the fourth powers of the absolute temperatures of the respective surfaces. As a result of this continuous radiation of energy, every point in the room is filled permanently with it, moving to and fro in all directions at a velocity of 186,000 miles per second. The heat radiation follows the same physical laws as does light radiation, the only difference being that of wave length. . . . . There is no fundamental difference between so-called *radiant heating*, and heating by means of ordinary free standing radiators, save for the fact that more of the heat with the former is radiant and less is convected. Radiant heating might therefore be defined as the type of heating in which more than 50 per cent of the heat supplied by the heating element is dissipated by the radiation process. . . . . In order that a person may be comfortable, he must dissipate heat at the same rate at which it is produced by the vital processes of his body—some by evaporation, some by convection and some by radiation. Thus there are various combinations of air temperatures and temperatures of the surfaces of a room which surround him which will lead to comfort. The charts presented here show heat gain or loss by convection with various air temperatures, from which can be found—on one of the other charts—the necessary *mean radiant temperature* of the surfaces of the room. A third chart shows the proper relationship between air temperature and mean radiant temperature. . . . . Studies have been made at Texas A & M College to determine rate of heat dissipated by concrete slabs in which heating coils are embedded, and the results are briefly reported here. The studies also were carried on to determine the extent to which heating coils can be used as reinforcement for the concrete slab. . . . . Methods of installing heating coils in America and Europe are explained briefly

A PORTION of the heat from a warm ceiling in a room is radiated to the walls and the remainder is radiated to the floor. The total radiation from a plane surface in all directions is π (or 3.1416) times that radiated in a direction normal to that surface. The walls and floor absorb about 90 per cent of the radiated energy received from the ceiling and reflect about 10 per cent.

Just as the ceiling radiates energy in all directions, so do the walls and floor. The intensities of the radiations from ceiling, walls and floor vary directly as the fourth powers of the absolute temperatures of the respective surfaces. Thus, if the temperatures of the ceiling and floor are 100 F and 72 F, respectively, the intensities of the radiations are to each other as 560^4 is to 532^4, or as 98 to 80. In other words, the ceiling at 100 F radiates about 23 per cent more energy per square foot than does the floor at 72 F.

As a result of this continuous radiation of energy from every point in the surface of the ceiling, walls and floor, the room is filled permanently (day and night) with radiation moving to and fro in all directions at a very high velocity—186,000 miles per second. The only difference between this heat radiation and light radiation is that the light radiation has a shorter wave length. Light radiation is sensed by the human eye; it enables one to see. Heat radiation can be detected only when it produces a sensation of warmth or of cold in the person exposed to it. Heat radiation follows the same physical laws as light radiation; when a room is lighted by one or more lamps on the ceiling, the entire room is filled with light radiation varying in intensity from place to place. The space under a table, for example, is lighted—but not so well as the space above the table. Similarly, if a room is heated by means of heating coils in the ceiling, the entire room is filled with heat radiation—including the space under the table, which is filled with heat radiation of a lower intensity than the space above the table. Every room is permanently filled with heat radiation, just as it is with air, no matter whether the room is supplied with artificial heat or not, or, if artificially heated, whether the heat is supplied by a free standing radiator or by a pipe coil in the ceiling, floor or wall.

There is, consequently, no fundamental difference between ordinary radiator heating and *panel warming,* or *radiant heating.* The difference between these two systems of heating is one of degree only. With ordinary radiator heating, about 30 per cent of the heat supplied by the radiator is dissipated by radiation and about 70 per cent by convection. With radiant heating (the heating coils being embedded in the ceiling, walls or floor) about 70 per cent of the heat supplied by the coils is dissipated by radiation and about 30 per cent by convection. Radiant heating might therefore be defined as the type of heating in which more than 50 per cent of the heat supplied by the heating element is dissipated by radiation.

How Radiant Temperature Affects Comfort

The sensation of warmth experienced by a person in any surrounding and at any time is influenced by the temperature of the air with which he is surrounded and by the *mean radiant temperature* to which he is exposed. Mean radiant temperature was explained on p. 360 of the June HPAC.

In order that a person may be comfortable, thermally, he must dissipate heat at the same rate at which heat is produced by the vital processes within his body. An adult at rest or in slow motion produces heat at the rate of about 400 Btu per hr. Of this amount, about 100 Btu is dissipated by the evaporation of moisture from the skin or from the lungs, and the remainder (about 300 Btu) must be dissipated as sensible heat by convection and by radiation. If, for example, 125 Btu per hr is

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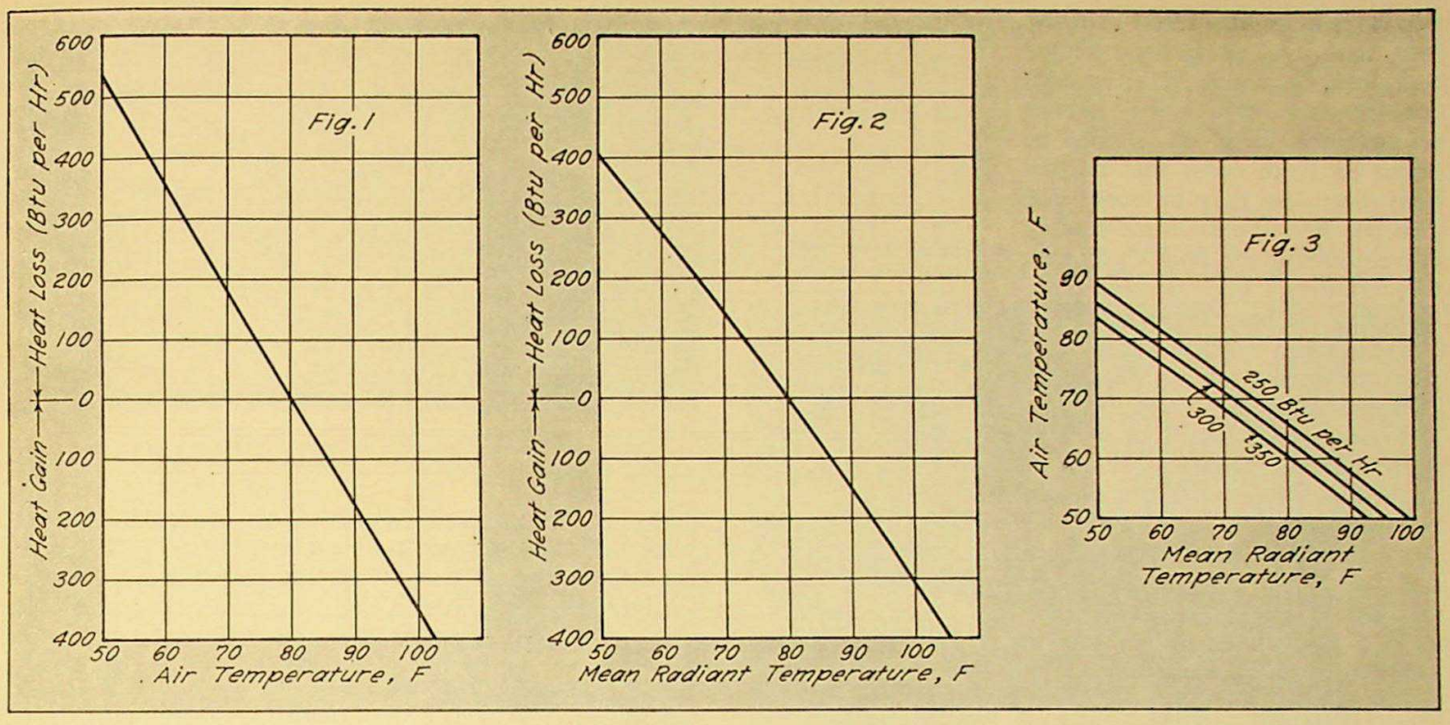


dissipated by convection, 175 Btu per hr must be dissipated by radiation.

The quantities of heat dissipated by a person by convection or by radiation can be calculated if the necessary data are available. During a recent investigation conducted by Dr. Yaglou at Harvard University with three male adults clothed in three-piece suits and at rest during the tests, it was found that comfort conditions were produced with the following three sets of temperatures: air 71 F and MRT 71 F; air 63 F and MRT 79 F; and air 59 F and MRT 85 F. Additional sets of temperatures similar to the three found experimentally by Dr. Yaglou could be calculated if one knew: (1) The area of the body surface exposed to convection currents. (2) The mean temperature of the exposed skin and clothing. (3) The film coefficient. (4) The area of the body available for radiation. (5) The radiation factor.

The two surface areas (Items 1 and 4) can be measured and may be assumed to be, on an average, 18 and 15 sq ft, respectively. The radiation factor may be assumed to be 0.156, as explained in June. This leaves two unknowns—the mean surface temperature and the film coefficient.

Determining Required Temperatures

If the mean temperature of the exposed skin and clothing is assumed to be 80 F and the corresponding film coefficient is 1 Btu per hr per sq ft per F temperature difference, the calculated heat losses for Dr. Yaglou's three sets of temperatures (71 F and 71 F, 63 F and 79 F, and 59 F and 85 F) will be, respectively, 291, 321 and 303 Btu per hr per person, according to the equations given on pp. 360 and 361 of the June HPAC. It seems that these calculated heat losses agree sufficiently well with each other so that a mean surface temperature of 80 F and a film coefficient of 1 Btu may be considered satisfactory for use in calculating comfort conditions for various combinations of air temperatures and mean radiant temperatures, for male adults clothed as were Dr.

Fig. 1—Heat loss or gain by convection for various air temperatures, in Btu per hr per person, according to the formula $Q = 18 \times 1\ (80 - t_a)$, where Q is Btu per hr per person, 18 sq ft is the area of the body exposed to convection air currents, 1 Btu per hr per sq ft per F temperature difference is the film coefficient, 80 F is the mean surface temperature of the body, and t_a is the temperature of the air in the room in degrees Fahrenheit

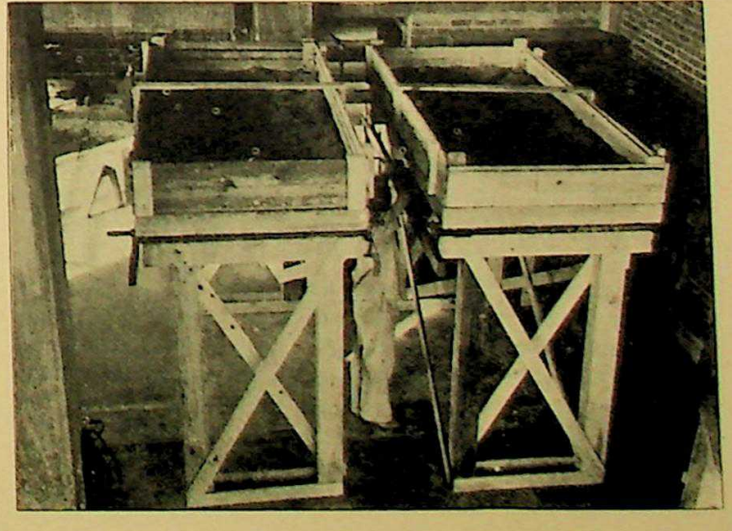
Fig. 2—Heat loss or gain by radiation for various mean radiant temperatures, in Btu per hr per person, according to the formula $Q = 15 \times 0.156\ [(540/100)^4 - (T_r/100)^4]$, where 15 sq ft is the area of the body available for radiation, 0.156 is the radiation factor for the body, 540 is the absolute mean surface temperature of body (460 + 80), T_r is the absolute mean radiant temperature of the room, and Q is amount of heat, Btu per hr per person

Fig. 3—Relationship between air temperature and mean radiant temperature for combined convection and radiation heat losses of 250, 300 or 350 Btu per hr per person, as indicated on curves

Yaglou's subjects. Naturally, comfort condition requirements vary with persons, with clothing and with states of rest and types of motion.

These data were used for the calculations for Figs. 1 and 2. These charts may be used as follows: If the air temperature is 60 F (Fig. 1), the heat loss by con-

Fig. 4—Laboratory test of heating pipe coil in concrete slab



vection will be about 350 Btu; the heat gain by radiation should therefore be about 50 Btu and; consequently, the mean radiant temperature (Fig. 2) should be about 83 F, in order that the net body heat loss may be about 300 Btu per hr. To facilitate finding corresponding air and radiant temperatures, Fig. 3 was constructed. It may be used as follows: If the mean radiant temperature in a room is 70 F, the corresponding air temperatures should be about 74, 71 or 68 F if the combined heat loss is to be about 250, 300 or 350 Btu per hr, respectively.

These values are for an adult male clothed in a three-piece suit and having a metabolic heat production rate of about 335, 400 or 465 Btu per hr, respectively. For different conditions and different persons, different combinations of air and radiant temperatures are necessary for comfort to result.

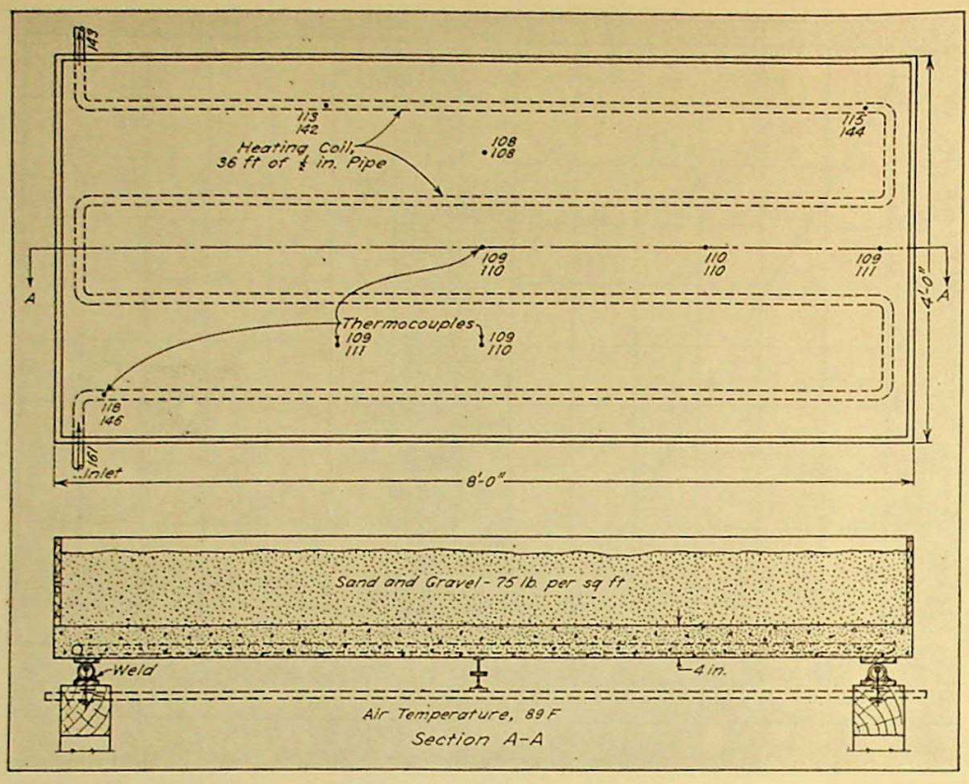


Fig. 5—Results of laboratory test of a pipe coil embedded in a concrete slab. The upper and lower figures show the temperatures in degrees Fahrenheit obtained at various locations for the upper and lower surfaces of the slab, respectively, with inlet and outlet water temperature values as indicated on the sketch

Figuring Building Heating Load

To determine the heating loads for a building equipped with radiant heating, one may proceed as for an ordinary heating system after having selected the desired indoor air temperature. The heat losses through the outside walls will be slightly higher for the same air temperatures than in the case of ordinary heating systems because the radiant energy emitted by the heating panels increases the temperature of the outside walls slightly. A good over-all check on heat loss calculation is that the total loss should be slightly lower than that for the ordinary heating system if the assumed indoor air temperature is slightly lower than the usual one.

Having determined the heat requirement of the several rooms in a building, the respective heating elements may be designed. Called heating panels, they consist generally of pipe coils placed in the ceiling, floor or walls, or suspended from the ceiling. The pipe coils are usually embedded in concrete slabs or covered with plaster.

Heat Dissipation from Coils in Slab

To determine the rate at which heat can be dissipated by a concrete slab in which heating coils are embedded and also the extent to which such heating coils can be used as reinforcement for the concrete slab, a series of tests was conducted at Texas A & M College, as shown in Fig. 4, and the results of one of these tests are given in Fig. 5. The concrete slab was reinforced only with the ½ in. pipe coil shown and was loaded with sand and gravel to 75 lb per sq ft. Nine thermocouples were attached to the upper surface of the slab and nine to the lower surface as shown by the dots in Fig. 5.

When water was flowing through the coil at the rate of 283 lb per hr, entering the coil at a temperature of 161 F and leaving at a temperature of 143 F and with, therefore, an average temperature of 152 F, the average temperature of the lower surface of the concrete slab was 144 F directly under the pipe coil, and 110 F midway between the coils. The average temperature of the upper surface of the slab was 115 F directly above the coil and 109 F midway between the coils, as shown by the temperature values lettered on Fig. 5.

Under these conditions, the concrete slab was dissipating heat at the rate of 10 Btu per hr per sq ft of external pipe coil surface, and per degree Fahrenheit temperature difference between the water in the pipe and the air beneath the slab. A considerable portion of the heat transferred from the pipe coil to the concrete slab was no doubt conducted into the bed of sand and gravel or emitted by the uninsulated edges of the slab. Consequently, the rate of heat transfer from the pipe coil to the slab found by experiment in this case is too high to be used in the design of panel warming systems.

When the heating coils are embedded in the concrete floor slab, a portion of the heat flows through the floor above the slab and the remainder flows through the ceiling below the slab. The division between these two quantities depends upon the degree of insulation of the slab above the coils. The quantity flowing upward generally varies from 5 to 30 per cent of the total heat dissipated by the pipe coil.

Methods of Installing Heating Coils

In the United States, it is customary to suspend the heating coils from the ceiling instead of embedding them in the concrete slab. By this method, the heating panel

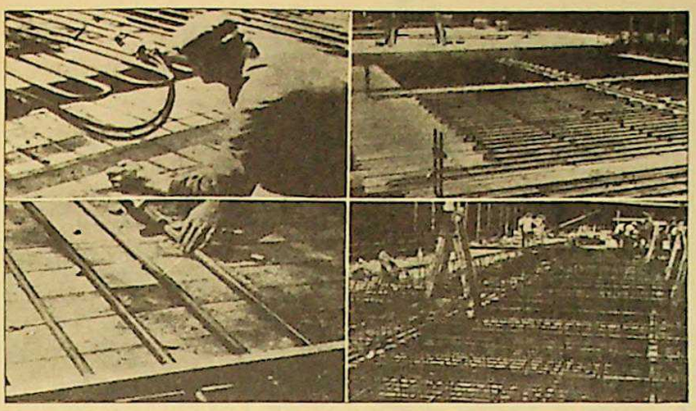
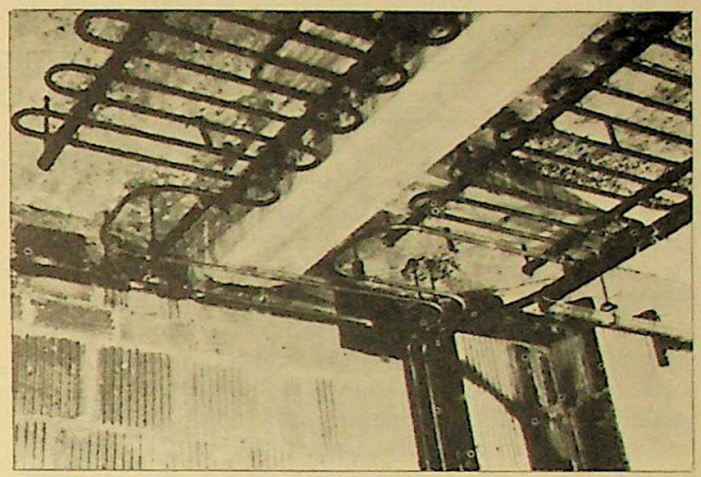


Fig. 6—Arrangement of pipe coils to be embedded in concrete slabs—European method

is constructed like the ordinary suspended ceiling, plastered on expanded metal and suspended from the floor construction, except that the heating coils rest directly on the expanded metal and are wired to it, and the plaster is applied so that the pipe coils are covered with it. An insulating layer is then placed over the heating coils and under the floor construction. The expanded metal serves the additional purpose of securing a uniform distribution of heat over the ceiling area.

The European method of placing heating coils in concrete slabs is shown in Fig. 6, and the American method of suspending the heating coils from the floor construction in Fig. 7.

Fig. 7—Arrangement of pipe coils to be enclosed in plaster and suspended from ceiling—American method



Radiant Heating and Cooling

How to Figure Total Heat Delivered by Panel and How to Calculate Pipe Coil Size Is Explained by F. E. Giesecke*

SUMMARY

Previous articles by Dr. Giesecke in the June and July issues of HEATING, PIPING AND AIR CONDITIONING have explained what radiant heating and cooling mean, have given the fundamentals of design of such systems, have shown the relationship between the room air temperature and the mean radiant temperature of the room surfaces, discussed heat dissipation from a pipe coil in a concrete slab, etc. . . . . This month, he tells us how to figure the amount of heat delivered by a ceiling, wall or floor heating panel and presents a rule for this calculation. He concludes with an explanation of figuring the size of pipe coil needed and shows an example of the calculation of a ceiling panel coil. . . . . The two charts simplify the determination of the amount of heat delivered to a room by radiation, and by convection and conduction, by ceiling, wall or floor heating panels

WHEN a room is heated by a panel placed in the ceiling, wall or floor, this panel forms a part of the surfaces enclosing the room and it may be assumed to be entirely enclosed by the room's surfaces. The heat transmitted by such a panel by radiation to the remaining portion of the room's surfaces may therefore be calculated by means of Equation 2, p. 360, June, 1940, HPAC. To avoid the necessity of making such calculations, the heat delivered by a panel by radiation may be taken from Fig. 1, as follows: To find the heat delivered by a heating panel when its temperature is 90 F, for example, to a room having a mean radiant temperature of 70 F for its enclosing surfaces, except the heating panel, find 90 in the lower margin, follow vertically up to the 70 F mean radiant temperature line, and on the left margin read about 19.5 Btu. Similarly, if the panel surface temperature is 105 F and the mean radiant surface temperature is 75 F, the rate of heat delivery by radiation is about 31 Btu per sq ft per hr, according to Fig. 1.

A heating panel delivers heat by radiation and by convection. The rate of heat delivery by convection depends upon the film coefficient; this varies with the velocity of the flow of air along the heated panel and also with the difference between the temperature of the panel and that of the adjacent air. Of three heating panels placed in the ceiling, wall, and floor, respectively, the film coefficient is evidently highest for the floor panel, because the heated air escapes readily from the floor, and lowest for the ceiling panel, because the heated air tends to remain stationary along the ceiling.

According to European research and experience (as reported by Max Hottinger of the Zurich Engineering School in *Gesundheits-Ingenieur*, 1938, Vol. 61, Nos. 33 and 34), the film coefficient may be selected with sufficient accuracy from the chart of Fig. 2. Thus, if the surface temperatures are, respectively, 80 F for a floor panel, 90 F for a wall panel and 105 F for a ceiling panel, while the air temperature is 68 F, the respective temperature differences are 12, 22 and 37 deg and the corresponding film coefficients are 0.90, 0.84 and 0.56 Btu per sq ft per hr per F from Fig. 2.

For these same temperature differences (80—68, 90—68 and 105—68) the heat delivered by radiation is 11.4, 21.5 and 37.7 Btu per sq ft per hr (Fig. 1) or 0.95, 0.98 and 1.02 Btu per sq ft per hr per F, respectively. It is sufficiently accurate to place each of these three values equal to 1. Then, after adding the heat delivered by convection, the total heat delivered by each of these three panels is 1.90, 1.84 and 1.56 Btu per sq ft per hr per F, respectively, for the floor, the wall and the ceiling panel, if it is assumed that the air temperature of the room is practically equal to the mean radiant temperature of the room.

Based on this calculation, it appears safe to adopt the following rule for finding the total heat delivered by a panel: Calculate the heat delivered by radiation and assume that the heat delivered by convection is equal to 80 per cent, 75 per cent, or 50 per cent thereof for floor, wall or ceiling panels, respectively.

Calculating Panel Size

The size of the heating panel for a room may be determined as follows:

1) Calculate the heat requirement of the room. (For example, assume 4000 Btu per hr).

2) Calculate or assume the mean radiant temperature (MRT) of the room (say 70 F).

3) Assume the maximum temperature of the panel (say 105 F for a ceiling panel, 90 F for a wall panel or 80 F for a floor panel).

4) Find from Fig. 1 the heat delivered by radiation for the three panels to be 36, 20 and 10 Btu per hr per sq ft, respectively.

5) Add to these values the respective percentages for heat delivered by convection and find the total heat delivered by the respective panels to be 54, 35 or 18 Btu per sq ft per hr.

6) Divide the total heat requirement of the room, 4000 Btu per hr, by the unit heat delivery of the panels and find the sizes of the panels to be 74 sq ft for the ceiling panel, 114 sq ft for the wall panel or 222 sq ft for the floor panel.

7) If the assumed panel temperatures differ from those suggested above in (3), make corresponding changes in the calculations.

Figuring Pipe Coil Size

Having found the required size of the panel and knowing the total quantity of heat required by the room, the required size of the pipe coil can be calculated if it is known how much heat will be transmitted from the pipe coil to the slab per foot of pipe and for the existing

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conditions. The pipe coils are generally constructed of ½, ¾ or 1 in. pipe.

It was shown in July, p. 423, that the heat conveyed from a ½ in. pipe coil in a concrete slab was at the rate of 10 Btu per hr per sq ft of external pipe coil surface per F temperature difference between the water in the pipe and the air beneath the slab. This value is too high to be used in design because the edges of the slab in the experimental set-up were not insulated, because a large portion of the total heat was, no doubt, absorbed by the bed of sand and gravel on the slab and because the radiant temperature of the concrete floor directly under the slab may have been considerably lower than the air temperature.

It has been found by experience that it is safe, under usual conditions, to base a heating panel design on a heat transmission value of about 3.5 Btu per hr per sq ft of external pipe surface and per F temperature difference water to air. This is roughly equivalent to 1.2 Btu per lineal foot of 1 in. standard weight pipe, 1 Btu per ft of ¾ in. pipe and 0.80 Btu per ft of ½ in. pipe.

It is evident that the unit rate of heat delivery by a pipe coil to its concrete or plaster jacket must vary with the distance between pipe coils and with the difference between the temperature of the pipe coil and that of the air. The unit rate of heat delivery increases as the distance between pipe coils increases and also as the temperature difference (water in pipe and air in room) increases. The unit rate of 3.5 suggested above is an average value.

In constructing pipe coils, it is customary to space 1 in. pipe from 12 to 16 in. on centers; ¾ in. pipe from 9 to 12 in. on centers; and ½ in. pipe from 6 to 8 in. on centers.

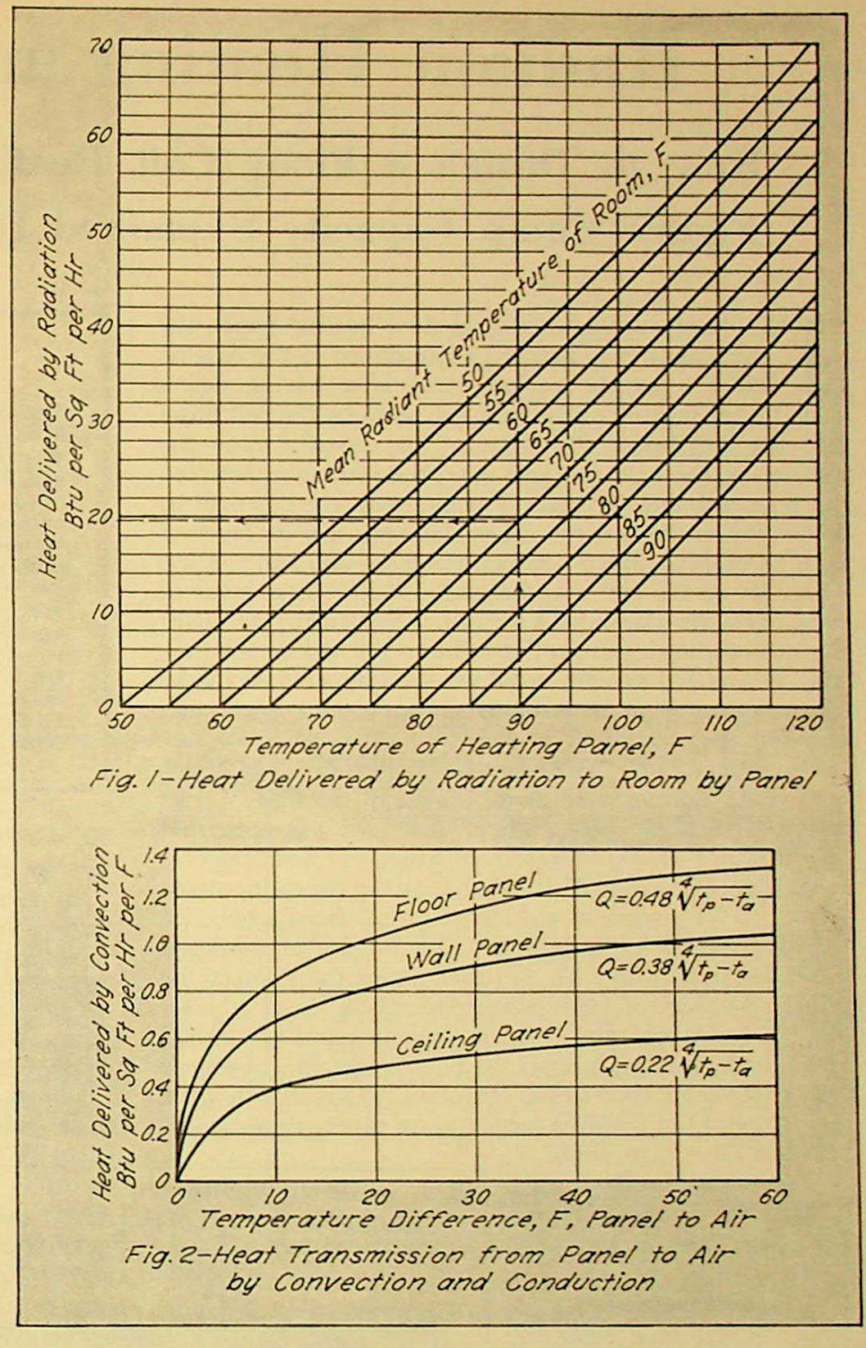

Fig. 1—Heat Delivered by Radiation to Room by Panel

Fig. 2—Heat Transmission from Panel to Air by Convection and Conduction

To design a pipe coil for a ceiling panel having an area of 74 sq ft and delivering 4000 Btu per hr to the room, assume the pipe size and spacing—say ¾ in. pipe spaced 9 in. on centers.

Assume that the insulation of the panel is such that 15 per cent of the heat flows upward and 85 per cent downward; the pipe coil must then deliver 4000/0.85 or about 4700 Btu per hr to the panel. If, say, 90 lineal feet of pipe are used, the heat delivery must be 4700/90 or about 52 Btu per ft. Since 1 ft of ¾ in. pipe delivers about 1 Btu per F temperature difference, water to air, this temperature difference must be 52 deg. Hence, if the air temperature is assumed to be 65 F, the mean water temperature must be 117 F.

If the water flows through the coil at a low velocity so that its temperature drop through the coil is 20 deg, the temperature of the water in the flow riser must be 127 F and in the return riser 107 F. If the velocity is higher, so that the water will cool only 10 deg in flowing through the coil, the temperatures in the flow and return risers must be 122 F and 112 F.

Radiant Heating and Cooling

How to Design a Floor Coil Heating Panel and How to Figure Pump Capacity Explained Here by F. E. Giesecke*

SUMMARY

Design of a pipe coil for a floor heating panel proceeds as for a ceiling panel as described last month, after first determining what portion of the heat delivered by the coil flows into the soil below the floor. This depends upon the location of the pipe coil and the insulation between the floor slab and the soil. Two cases are discussed here, one with the coil embedded in a concrete slab under which is a layer of sand or cinders and the other with the coil embedded in the layer of sand over which is the floor slab. . . . . Figuring the pump capacity for a panel heating system of the forced circulation hot water type is also considered this month, and Dr. Giesecke concludes with a note on the accuracy of the calculations. . . . . This is the fourth of Dr. Giesecke's articles on radiant heating and cooling and another will be in HEATING, PIPING AND AIR CONDITIONING next month

TO design a pipe coil for a floor heating panel, the calculation may proceed as described in the August HPAC for the ceiling panel after having determined what portion of the heat delivered by the coil flows into the soil below the floor. This depends upon the location of the pipe coil and upon the insulation between the floor slab and the soil. For example, the coil may be embedded in the concrete floor slab with a 6 in. layer of sand or cinders placed between the floor slab and the soil (Fig. 1) or the coil may be placed in the 6 in. layer of sand below the floor slab (Fig. 2). To calculate the quantity of heat flowing from the coil into the soil, it is necessary to know the depth at which the temperature of the soil under the floor remains constant and what that constant temperature is.

Professors L. G. Miller and C. H. Pesterfield of Michigan State College have made studies of the flow of heat into and through soils. They found, for example, that at a distance of 200 ft from a building, the soil temperatures increased from 25 F to 40 F as the depth increased from 1 to 7 ft; while at a distance of 5 ft from a building the temperature increased from 30 F to 50 F as the depth increased from 1 to 5 ft, and that under the floor of the unheated basement (temperature about 55 F) of a building, the soil temperature was practically constant at 75 F at a depth varying from 1 to 5 ft below the basement floor. It seems reasonable, therefore, to assume that the soil temperature under a heated floor panel remains constant at 70 F at a depth of 3½ ft below the floor slab, in localities having a climate not colder than that of East Lansing, Mich.

Assume that in one case (Fig. 1) the pipe coils are placed in the concrete slab 2 in. below the surface, and in the other case (Fig. 2) they are in the bed of sand 1 in. below the concrete slab; assume also that the thermal conductivities of the concrete,† sand and moist earth are, respectively, 8, 3 and 12 Btu per in. per sq ft per hr per F, and that, in both cases, the floor surface temperature is 80 F and that heat is being delivered by the floor slab to the room

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†The thermal conductivity of concrete varies with the density and with the moisture content of the concrete. The value 8 was selected for this illustration to represent dry concrete of average density. For more accurate calculations the value of k should be taken from the ASHVE Guide for the particular concrete to be used.

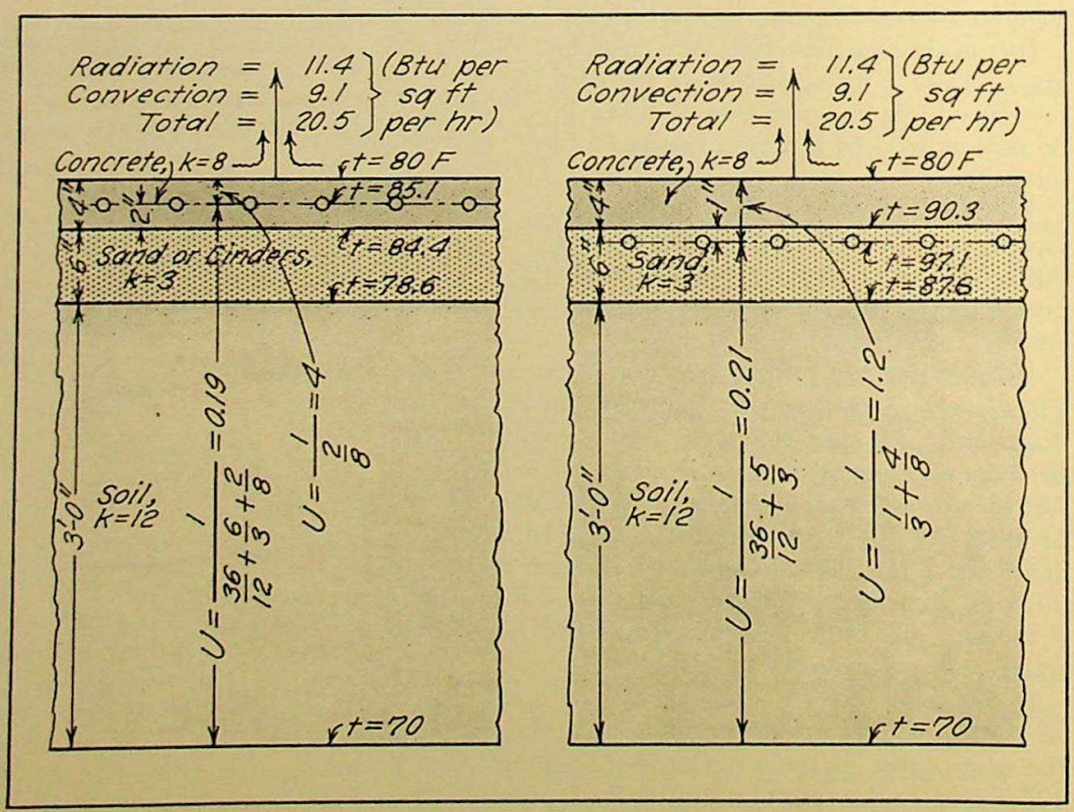


Fig. 1 (left)—This sketch represents a cross section through a floor heating coil embedded in a 4 in. concrete slab under which is a 6 in. layer of sand or cinders. Temperature at the bottom of the 3 ft of soil is assumed—on the basis of tests—to be 70 F. The text explains how to figure the amount of heat the coil must deliver in order that a total of 20.5 Btu per sq ft per hr will go to the room. . . . . Fig. 2 (right)—This is the same as Fig. 1, except the pipe coil is embedded in the layer of sand instead of in the concrete, as it is in Fig. 1

at the rate of 20.5 Btu per sq ft per hr. The flow of heat into the soil may be calculated as follows for the two cases shown:

If the coils are placed in the concrete slab (Fig. 1) and the mean temperature of the surface of the slab is 80 F, the mean temperature of the central portion of the slab (the plane in which the coils are placed) must be sufficiently higher so that the heat will flow from there to the upper surface of the slab at the rate of 20.5 Btu per sq ft per hr. Since the conductivity of the concrete is 8, the conductance of the 2 in. layer above the coils is 4, and the difference in temperature between the two planes must be 20.5 divided by 4 or 5.1 deg; hence the temperature of the central plane must be 80 + 5.1 or 85.1 F, as shown.

To find the rate of heat flow from the center of the concrete slab having a temperature of 85.1 F to the layer of soil 44 in. below, and having a temperature of 70 F, it is necessary to find the conductance of the 44 in. layer of materials consisting of 2 in. of concrete, 6 in. of sand, and 36 in. of soil. The respective conductances of these three layers are 8/2, 3/6, and 12/36; the respective resistances are therefore ¼, 2 and 3; the total resistance is 5.25 and the total conductance is 0.19, as shown in Fig. 1. The flow of heat into the soil is therefore at the rate of 0.19 (85.1 — 70) or 2.9 Btu and the coils must deliver heat to the concrete slab at the rate of 20.5 + 2.9 or 23.4 Btu per sq ft per hr. The size of the coil may be designed as explained last month for the ceiling panel.

The calculation for the flow of heat in the second case (Fig. 2) is similar to that just explained.

To find the mean temperature of the layer of sand in which the coils are placed (Fig. 2) it is necessary to know the conductance of the 5 in. layer of materials consisting of 1 in. of sand and 4 in. of concrete. It is 1.2, as shown in Fig. 2. The temperature difference between the two planes is therefore 20.5 divided by 1.2 or 17.1 deg and the mean temperature of the layer of sand is 80 + 17.1 or 97.1 F.

Heat will flow from this layer of sand to the 70 F layer of soil 41 in. away at the rate of 97.1 — 70 multiplied by the conductance of the 41 in. layer of materials, which is 0.21, as shown in Fig. 2, or 27.1 × 0.21 or 5.7 Btu per sq ft per hr. The coil must, therefore, deliver heat to the layer of sand in which it is embedded at the rate of 20.5 + 5.7 or 26.2 Btu per sq ft per hr.

The coil can be designed as described for the ceiling panel; however, the rate of heat transfer from the coil to the sand in which it is embedded is, no doubt, lower than to a slab of concrete in close contact with the coil, and it is necessary to use a larger coil than would be necessary if the coil were embedded in concrete.

To calculate the capacity of the pump for a forced circulation panel warming system, if the heat loss of a building is 120,000 Btu per hr and the temperature drop through the coils is 20 deg, the pump must deliver 120,000/20 or 6000 lb per hr of water or about 12 gpm. However, if the water cools only 10 deg in flowing through the coil, the pump must deliver about 24 gpm. The friction head (that is, the head against which the pump must operate) is calculated like it is with any other forced hot water heating system. For example, in the system shown in Fig. 3, the total friction head consists of the partial heads in the following five sections:

1) In the flow main from the boiler to point 2.

2) In the flow riser from point 2 to point 3.

3) From the flow riser at point 3 through the coil to the return riser at point 4.

4) In the return riser from point 4 to the return main at point 5.

5) In the return main from point 5 through the circulating pump and through the boiler to the point of beginning.

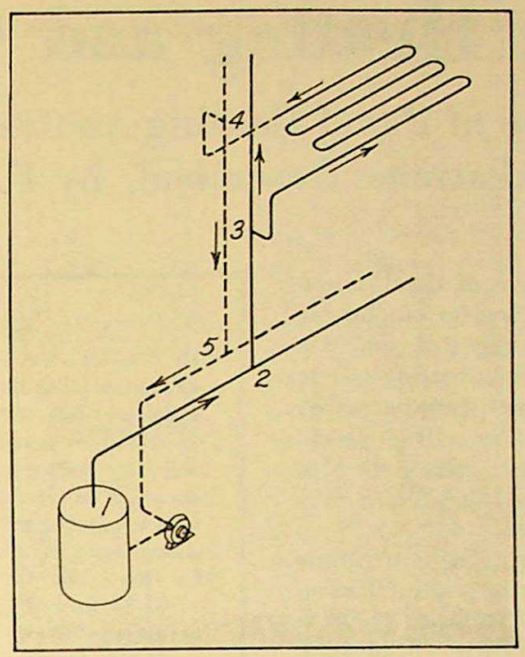


Fig. 3—Friction head against which the pump must operate is calculated like it is with any other forced hot water heating system. In this case, the total friction head is made up of the partial heads in sections *1-2, 2-3, 3-4, 4-5* and *5-1*

To calculate the loss of head in the coil, it is only necessary to treat it as a section of a circuit consisting of a certain number of feet of pipe and a certain number of tees and ells; in doing this, each return bend may be placed equal to one elbow—this is not quite accurate but the resulting error is on the side of safety. Having found the number of feet of pipe and the number of elbow equivalents in the coil circuit, its friction head is found in the usual way. Since the friction head in pipes and fittings varies almost as the square of the velocity, it is evident that the power required to force the water through a panel warming system is almost eight times as great when the water cools only 10 deg in flowing through the coil as when it cools 20 deg, because the pump must circulate twice as much water against a head almost four times as high.

The coils should whenever possible be connected to the risers so that the water flows upward through the coils in order that any air which may be trapped in the coils can escape in the direction of water flow.

A panel heating system cannot be designed with the same degree of accuracy as an ordinary radiator system without very complicated calculations, because the manner in which the pipe coils are covered with concrete or plaster is variable and also because the quantities of heat dissipated by radiation and by convection are variable. If the method suggested above is applied, the result should be sufficiently accurate so that satisfactory results can be secured by a variation in the water temperature. For example, if a system is designed for a water temperature of 100 F, its heat output can be increased about 30 per cent by raising the water temperature to 110 F, or it can be decreased about 30 per cent by lowering the water temperature to 90 F. This range is certainly wide enough to protect against probable design inaccuracies.

Radiant Heating and Cooling

Warm Air Type of Panel Heating Analyzed, and Other Types of Installations Described, by F. E. Giesecke*

SUMMARY

Dr. Giesecke has explained in previous months the fundamentals of radiant heating and cooling, has presented necessary data for figuring such installations, and has described in detail the calculations for designing floor coil and ceiling coil heating panels. This month, he discusses an interesting suggestion for warming a ceiling with air so that the ceiling will heat a room by radiation. Assuming a room of certain dimensions and heat loss, he shows how the quantity of air and its temperature could be figured, giving enough information so that the reader can follow through the explanation and apply the method in practice. . . . To conclude this month's discussion, the author briefly describes a number of radiant heating and cooling installations. Particular attention is given to a department store in Zurich, Switzerland, one part of which has ceiling pipe coils for heating in winter and cooling in summer. The coils also supply part of the steel reinforcement for the concrete slabs. Studies were made of the possibility of condensation, and of the results obtained in cooling service, and the results are graphed. Another installation of particular interest is in an operating room in a Grand Rapids hospital, which has wall panels for cooling the surgeons by radiation

AT a recent meeting, E. A. Jones of the Wisconsin chapter of the American Society of Heating and Ventilating Engineers suggested that the cost of installing a ceiling panel or radiant heating system might be materially reduced if the panel were heated by a blanket of warm air flowing along the ceiling instead of by warm water flowing through pipe coils embedded in the concrete slab. This plan seems feasible if it may be judged by the following calculations.

If the room shown in Fig. 11 on p. 358 of the June HPAC has a heat loss of 6000 Btu per hr and its heating panel is to be designed for an air temperature of 68 F and a mean radiant temperature (MRT) of 74, and the entire ceiling (12 ft by 15 ft) is to be the heating panel, the heat dissipation of the ceiling must be at the rate of 6000/180 or 33⅓ Btu per sq ft. If one-third of this heat is delivered by convection, about 22 Btu per sq ft per hr must be delivered by radiation; the ceiling temperature must therefore be 96 F, according to Fig. 1, p. 485, August HPAC.

If the blanket of warm air is to move across the ceiling at a rate of 50 fpm or 0.57 mph, the value of the film coefficient would be about 2, according to the ASHVE Guide. If, to be safe, its value is placed at 1.5, the mean temperature of the blanket of warm air in contact with the ceiling must be 96 F + (33⅓ ÷ 1.5) or about 119 F. If the blanket of warm air is 9 in. or 0.75 ft thick, the volume moving across the ceiling in one hour is 12 × 0.75 × 50 × 60 or 27,000 cu ft per hr. The weight of 1 cu ft of air at 70 F (530 F absolute temperature) is 0.075 lb; therefore the weight of this volume of air at 119 F (579 F absolute temperature) is 27,000 × 0.075 × 530/579 or 1850 lb. If the specific heat is placed at 0.25, the air will deliver 1850/4 or 463 Btu per hr to the ceiling heating panel for every degree its temperature is lowered. Therefore, to deliver 6,000 Btu per hr, its temperature must be lowered 6000/463 or 13 deg.

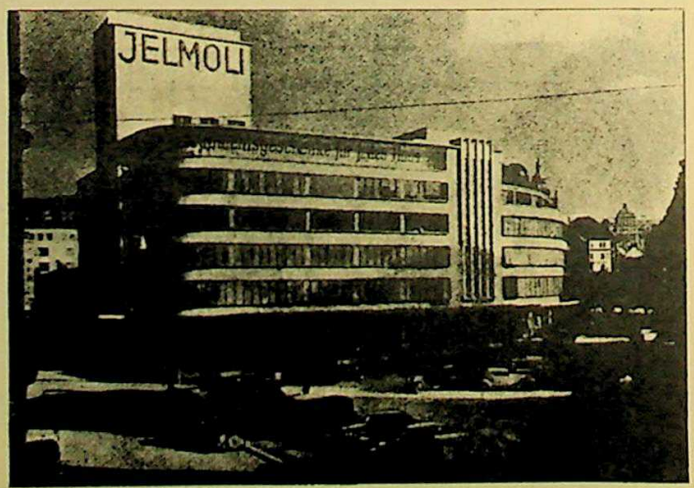
Hence the air should enter the room through several wide registers just beneath the ceiling at one end of the room at a temperature of 126 F and leave through similar registers at the other end of the room at a temperature of 113 F. The current of warm air, flowing along the ceiling, would then deliver 6000 Btu per hr to the ceiling panel by conduction, and the ceiling panel would deliver 6000 Btu per hr to the room, part by radiation and part by convection. In addition, the air ducts in the end walls leading to and from the registers would heat the end walls so that these walls would also become heating panels. By virtue of the convection air currents which would be produced by the heating ceiling panel, the air in the warm air blanket would be mingled to a certain extent with the room air, and the incoming warm air could be treated as supply air which could be filtered and humidified so that this type of panel warming would partake of the nature of air conditioning.

From a theoretical point of view, this system suggested by Mr. Jones seems quite attractive.

Panel Warming Installations

Since panel warming was first developed in England, the largest number of such installations exist there.

Fig. 1—The newer part of this Swiss store has ceiling panel coils for heating in winter and cooling in summer



*President, American Society of Heating and Ventilating Engineers. Professor Emeritus, Heating, Ventilating and Air Conditioning, Agricultural and Mechanical College of Texas.

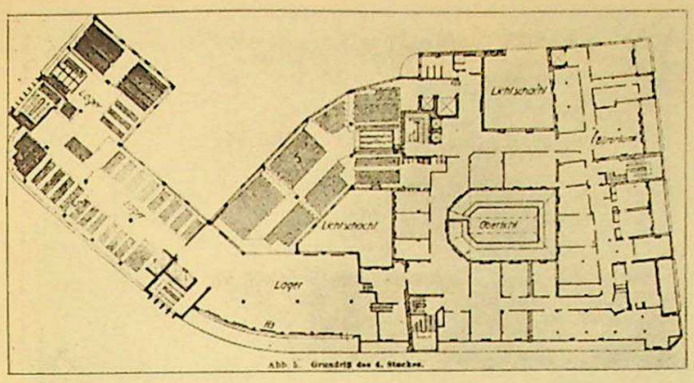


Fig. 2—This plan gives an idea of the coil installation for the department store shown in Fig. 1. The pipe coils are used for heating, for cooling, and reinforcing the concrete slabs

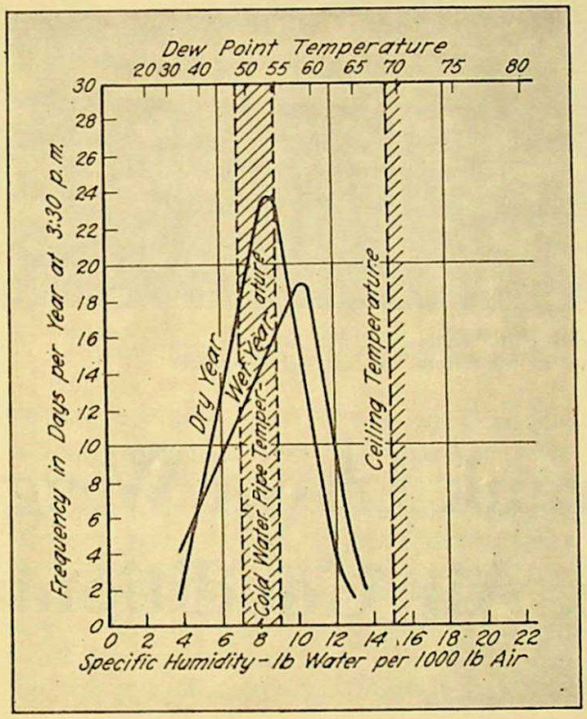
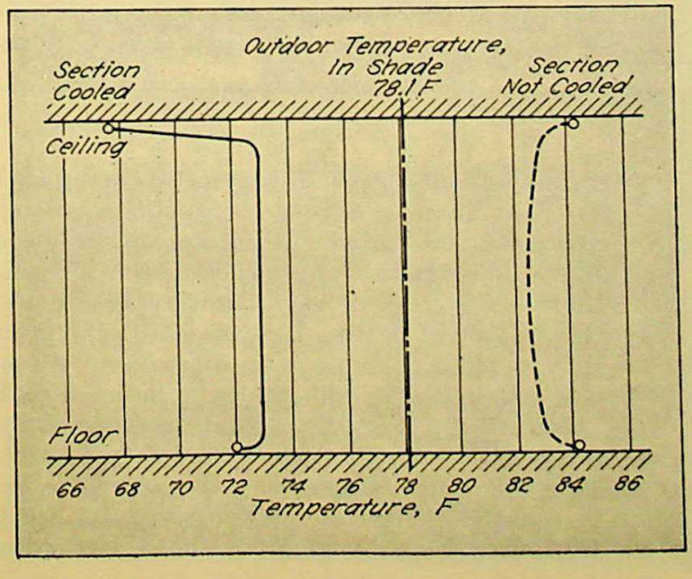

Dew Point Temperature
20 30 40 50 55 60 65 70 75 80
Frequency in Days per Year at 3:30 p.m.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Dry Year
Wet Year
Cold Water Pipe Temper.
Ceiling Temperature
0 2 4 6 8 10 12 14 16 18 20 22
Specific Humidity - lb Water per 1000 lb Air

Fig. 3—A study made for the building of Figs. 1 and 2 indicated that if the ceiling temperature is not allowed to fall below 70 F for cooling service in summer there is no danger of condensation

Fig. 4—Results of cooling by ceiling panels in the Swiss department store on a typical August day are shown on this chart



There are also many installations in other European countries but comparatively few in the United States and Canada. A very interesting installation is shown in Figs. 1 and 2—a department store in Zurich, Switzerland. The older portion of the building was erected about 12 years ago and equipped with standard radiators; the newer portion was built about three years ago and equipped with ceiling panels. The interesting feature in this building is that the coils are used to heat the building in winter, to cool it in the summer, and to supply a portion of the steel reinforcement needed for the concrete slabs. To determine whether the coils could be used for cooling without danger of condensation on the ceiling, a study was made of the specific humidity as shown in Fig. 3, and it was found that if the ceiling temperature is not allowed to fall below 70 F there is no danger of condensation.

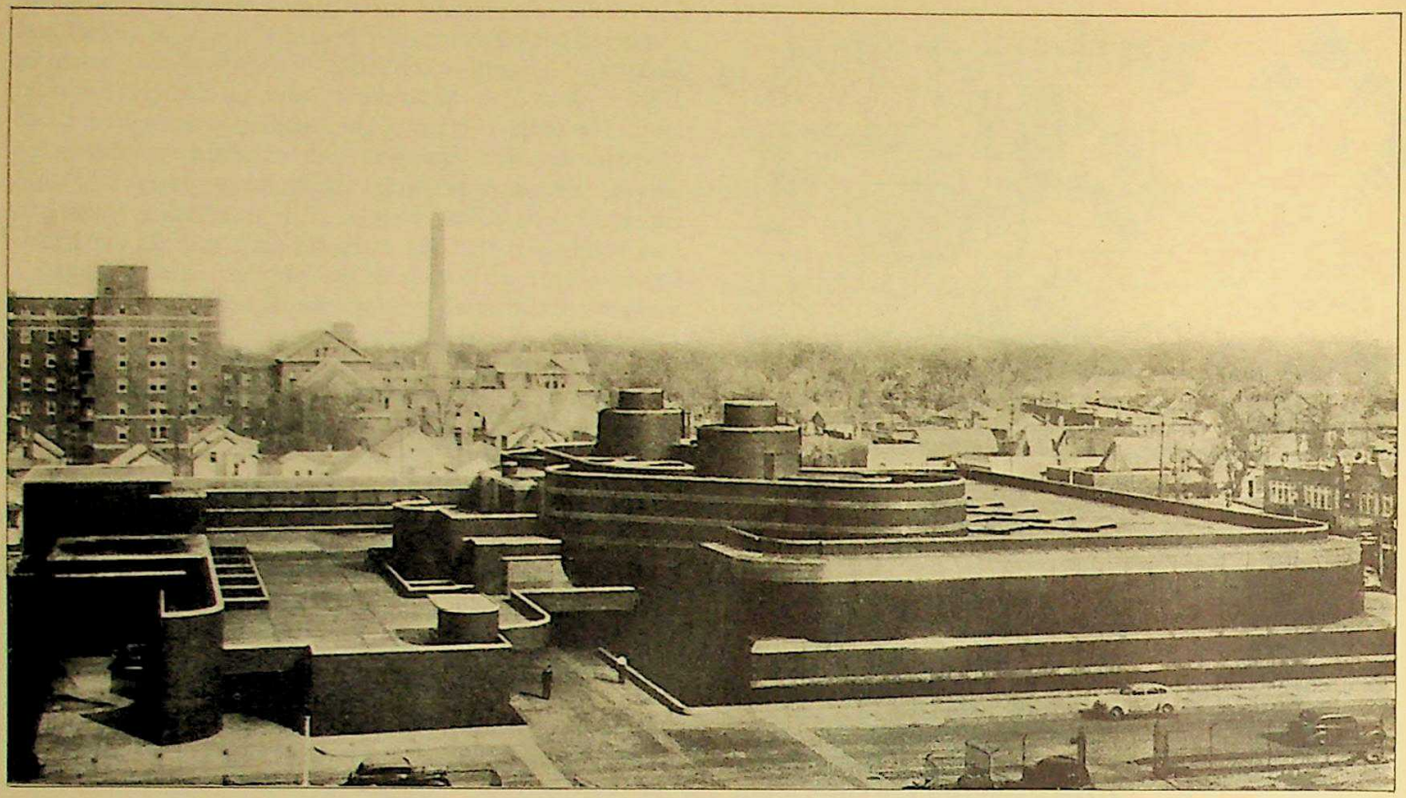
The results of the summer cooling for a typical August day are shown in Fig. 4. The temperature in the new portion of the building is about 10 deg lower than in the old portion, which is not cooled. Temperature of the cooling water was about 50 F.

The first important building equipped with panel heating in the United States was the British embassy building in Washington, in which the heating was installed under the direction of Wolff & Munier. Another building equipped in a similar manner is the Metropolitan State Hospital, Waltham, Mass. A panel heating system installed in the Everett, Wash., high school under the direction of E. L. Weber was described in the May, 1940, HPAC.

Radiant Cooling in Hospital

An interesting example of a radiant cooling system may be seen in one of the operating rooms of the Blodgett hospital in Grand Rapids, Mich., described by Drs. C. A. Mills and John Gorrell in the December, 1938, HPAC. In this installation metal sheets, about 36 x 120 in., are suspended from the walls at an elevation equal to that of the operating table. These sheets are cooled by pipe coils attached to their rear surfaces through which 40 F water is circulated. The condensate which forms on the metal sheets is collected in troughs underneath the sheets and discharged. The surgeons operate between the two cooled metal sheets and, in that way, dissipate a considerable portion of their body heat by direct radiation to the cold panels.

There are a number of other installations in existence, both for heating and for cooling, but space is not available to describe additional details.



S. C. Johnson & Son's ultra-modern office building, showing the enclosed court entrance and the "nostrils" which house the dehumidifiers and serve as air inlets and mixing chambers

Building Designed by Frank Lloyd Wright Features Floor Heating, Air Conditioning

By Victor Walters*

AT Racine, Wis., stands the ultra-modern office building recently completed for S. C. Johnson & Son, Inc.—epitome of the logic and functionalism in architecture of which Frank Lloyd Wright, its designer, is the untiring champion. Though every adjective expressing fantasy has been applied to the features of construction and appearance, its famed architect has proved his reasoning by the extraordinary utility of the structure.

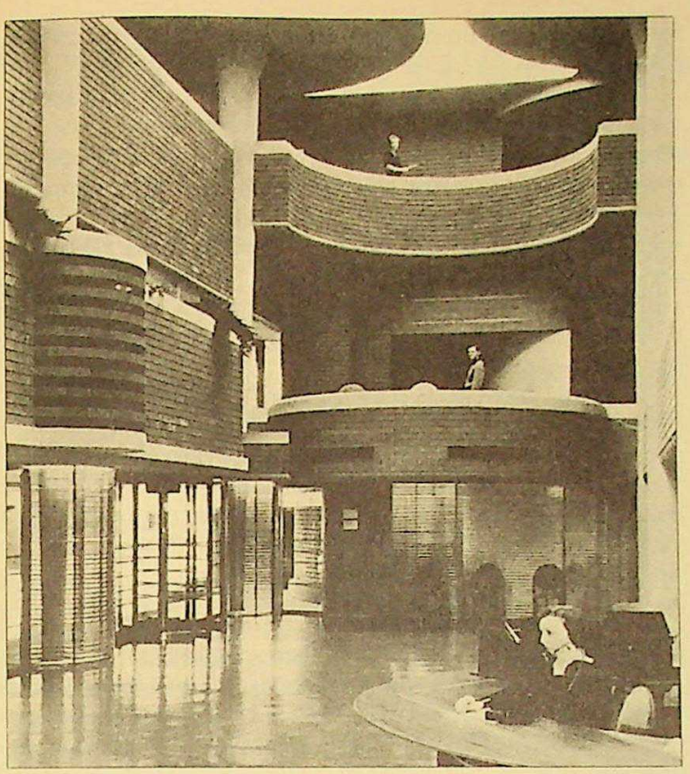
Basically the windowless office building presents a primary problem in air conditioning and heating, and since the design of the Johnson building called for windowless construction, Mr. Wright developed his plans with several unique angles. Inevitably air conditioning becomes a fundamental consideration in modern building planning although the Johnson building embodies features which may have a vital effect on the distinct trend toward windowless construction.

First among the unique features is the heating system for the general office which involves the principle of "permeation" rather than convection or conduction; in more common phraseology, this method is called floor heating. This type of system was used because it was believed that conventional heating methods could not be adapted to the construction details of this office, which is a large workroom 210 by 130 ft with a 20 ft ceiling.

The use of 3 in. cork insulation for walls and roof resulted in minimum heat losses while the entrance to the building from an enclosed court and driveway further reduced this factor. Though a windowless building,

In the unique office building recently completed for S. C. Johnson & Son, Inc. (Johnson's wax) at Racine, Wis., pipe coils in the concrete floor slab are used for heating. The building is essentially one large workroom, and it was felt that this method of heating was more adaptable to it than would be a more conventional type of system. Designed by the famed architect Frank Lloyd Wright, the structure has many novel features and is completely air conditioned. . . . . This description supplements an earlier preliminary article which was published in the April, 1938, HEATING, PIPING AND AIR CONDITIONING

*Sales Engineer, Westerlin and Campbell Co.

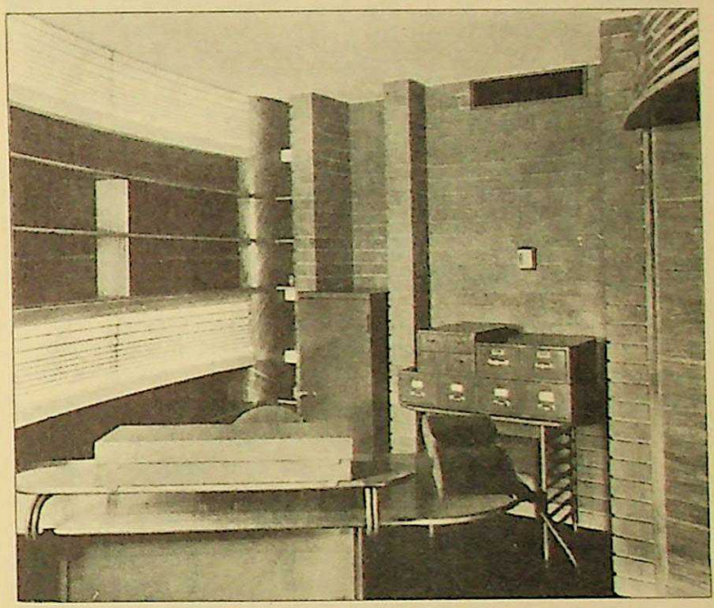


Entrance hall showing tubular enclosures and walls through which light is admitted. Note also the air distribution grilles in the mezzanine enclosure

daylight is admitted through bands of clear glass tubes encircling the structure, so that the radiant effect of the sun is also considerable. The coefficients of heat transmission, the temperature of the heating medium, and the required surface area were assumed and all other design factors were based on these assumptions. Steam was selected as the heating medium because the company's nearby power plant could be utilized, while it was felt the maintenance of vacuum conditions in the system would reduce pipe corrosion. Since it was desirable to hold temperatures comparable to those in a hot water system, sub-atmospheric steam was specified.

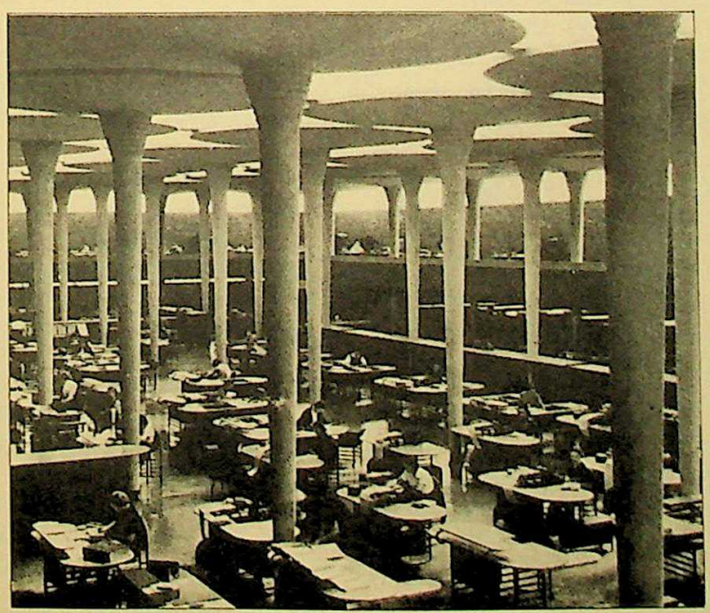
Actual installation of the heating equipment began with the placing of wood blocks, at proper grade, under the piping. The wrought iron pipes were then field welded and clamped to precast concrete blocks. The piping was then covered with coarse gravel, about 5 in. thick below the pipes and 3 in. above. A 6 in. concrete slab was poured over the gravel and finished with felt and rubber tile.

Steam at 75 lb pressure is piped from the power plant, reduced to 5 lb at the first stage, and through a second manual valve to sub-atmospheric pressure which may be varied from 0 to 28 in. vacuum. Each of the five control zones of the floor piping system is equipped with two thermostatic devices connected with a central panel which keeps conditions averaged, by operation of a steam valve, to maintain a slab temperature of 60 to 75 F.



Typical private office on the third floor of the building. This view shows clearly the glass tubes through which light is admitted, the air distribution grille, and the control thermostat

Interior view of the general office area. This space is heated by means of the floor radiation system while the ventilating and conditioned air distribution is accomplished through grilles in the wall surrounding the balcony

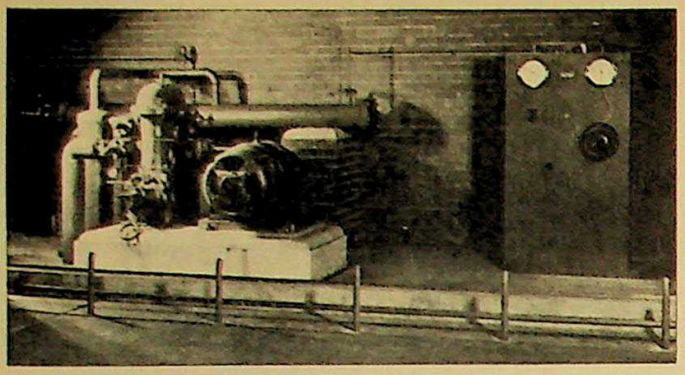


Of particular interest was the architect's assumption that the heating method would result in a substantial reduction in heat loss by comparison with convectional methods since the heat warms the building material rather than passing through it. In addition, he anticipated the air temperatures required for complete comfort will be 10 F less than usual.

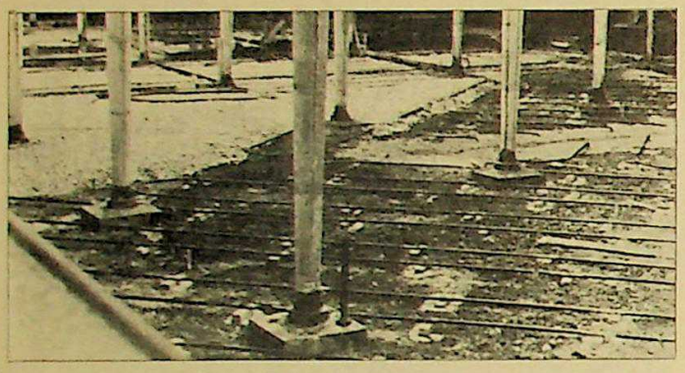
The executive offices are heated by booster coils placed in the ventilating ducts and controlled by modulating thermostats. Tempering and reheating coils in the ducts, thermostatically controlled, provide 75 F air for ventilating while the air washers are arranged to furnish humidification during the heating season.

The cooling phase of the comfort cycle is slightly less revolutionary than the floor heating system. That it contributes as much to the efficient functioning of the offices has been acknowledged by the management after a season's experience in the structure.

The air conditioning specifications for the cooling phase called for 80 F dry bulb and 50 per cent relative humidity when outdoor conditions of 95 F dry bulb and 75 F wet bulb were recorded. Compensating control



The condensing system which serves one of the two complete zones, providing complete summer air conditioning for the entire building



Construction view of the early stages showing the floor heating piping arrangement and fill

maintains the relationship between conditions outdoors and within the conditioned space in conjunction with automatic air mixing bypass devices and complete accessory equipment.

The duct work for air distribution is of the built-in type, and the ducts are part of the building structure, with framed outlets provided with manual friction type louvre dampers and special deflection grilles.

This is literally a "breathing" building with two "nostrils" extending above the roof level which serve as air inlets and house the fans and washers. The incoming air is cooled, dehumidified, and mixed in these chambers and then circulated through the structure.

Two complete systems were installed, each with its own condensing system, using a motor driven, vertical, single acting "Freon-12" compressor, and arranged for direct expansion of the refrigerant in coil type dehumidifiers which are situated in the nostrils. This arrangement of equipment was adopted because of its flexibility and to take advantage of operating economies available with zoning. Each condensing unit has a capacity of 50 to 57½ tons and is powered with a 60 hp slip ring motor with manual starter.

The fans have sufficient capacity for circulating 260,000 cfh of conditioned air; this air is introduced through specially designed outlets at a comparatively low level without noise or drafts. Return air is delivered to the dehumidifier chambers through built-in masonry ducts similar to those provided for the supply plenum.

Performance of System

Although the building has been occupied only since last May, the heating and air conditioning systems have been operated since October, 1938. Thus a complete cycle has been observed and the success of the design confirmed.

With a floor temperature of 72 F, the building was maintained at comfort zone conditions, the five control zones functioning in perfect coördination. The air distribution system has been balanced, and the original air volume calculations exceeded slightly in actual practice.

Though the cooling load was increased substantially by the installation of lighting of almost twice the design wattage, the summer air conditioning system, with an occupancy load, functioned satisfactorily.

The air conditioning and floor heating sytems were engineered and installed by the Westerlin and Campbell Co. Frank Lloyd Wright, in addition to his services as architect, assumed personal supervision of construction, which was handled by B. E. Wiltscheck, the general contractor.

[Photographs courtesy York Ice Machinery Corp.]

OWNER CITES ADVANTAGE OF AIR CONDITIONING

We have just finished the season of operating our air conditioning system on the cooling cycle. There is no doubt in our minds that during the summer months this can be credited with a large percentage of increased production over buildings without cooling. All department heads report that as a result of air conditioning (1) machine operation errors have been reduced, (2) absenteeism has been lessened, (3) heat weather fatigue has become negligible, (4) as a result of controlled temperature and humidity, the daily production of work is nearly constant regardless of outside conditions, (5) it is possible for employees to maintain a better appearance, (6) employees put in more nearly a 100 per cent working day.

The new office building is completely sealed from the outside and all air entering the building passes through air washers, resulting in an easier job of maintenance and a healthier place in which to work. During the hay fever season many of our employees hated to leave the building, for during working hours they found great relief due to the air conditioning.

—S. C. Johnson & Son. Inc.

Cathedral Heated by Underfloor System

Similar Scheme Used in Hospital

AMERICAN heating engineers are becoming more and more interested in various methods of radiant heating. While there are few such installations in the United States, the scheme has been widely adopted, in various forms, in England.

One of the outstanding jobs is the underfloor heating system for the cathedral in Liverpool. The plan and section shows the formation of the channels under the floor. The heater, indicated at *A*, warms the air and

By **T. Napier Adlam***

Before establishing in the United States, Mr. Adlam was intimately connected with the development of methods of radiant heating in England; he has continued his interest in the subject, and has explained the principles and practice of radiant heating to American engineers. . . . One of the notable installations is the underfloor system for the cathedral in Liverpool, which is described here. A similar scheme has been employed for multi-storied buildings, and a system of this type is also described

the fan *B* circulates this air over the heater and through the ducts formed in the floor. The air system is entirely sealed, so that no air can escape into the building or be lost in any way. The base or underfloor is virtually a concrete raft which extends throughout the nave, chancel, and the north and south transepts and this forms a base for the circulating flues.

Concrete divisional walls *F*, about 2 in. wide by 12 in. deep and 10 in. apart, were built up from the concrete base to form supports for the floor proper and the channels between these divisional walls are connected up alternately to the main warm air flow and return ducts. The warm air is carried along the main duct *C* where part of the air passes through the openings *G* into flues *D*. The sizes of the openings at *G* were calculated to carry the correct amount of air to each duct depending on its length. The return air from all the channels in the floor is conveyed through the small openings *H* into the main return duct *E*, where it is conveyed back to the fan.

Slate slabs about 6 ft by 3 ft and 1¼ in. thick were placed on the top of the divisional walls, leaving each flue or channel with a net area of 12 in. by 10 in. The slabs supported in this way are sufficiently strong to support any possible weight, while on top of the slate slabs were placed white marble slabs about ¾ in. thick. These marble slabs were bedded down with cement to form the finished floor of the cathedral. Thus, the whole floor became one large radiator and is reputed to be the largest single radiator in the world.

The channels in the floor are stepped up where the riser steps are formed from the nave to the chancel, so that the whole floor surface is heated uniformly and the extreme end of the chancel is equally warm with the rest of the cathedral. Since every part of the floor is practically at the same temperature there are no down drafts whatsoever, and no objectionable flickering of the candles—which often takes place at the altar in most churches and cathedrals heated with convection systems.

Temperature Gradient in Cathedral

There are a few items of interest associated with this installation which are worthy of special notice. The height of the cathedral inside is about 113 ft and the triforium walking way which is carried along both sides at a height of 97 ft above the floor makes it possible to make very accurate observations of air conditions at high level.

When the temperature of the air taken at 4 ft above the floor was 60 F, it was found that the air temperature at the triforium level, more than 90 ft above, was 58½ F—just 1½ F lower than at 4 ft above the floor. It seems to me that no other known method of heating could create these ideal conditions in such a high building, because I have conducted tests in similar cathedrals where warm air systems have been installed and the temperature at high level is much too hot to be comfortable. It has been found after several years experience that the inside temperature of 58 to 60 F gives perfect comfort under all outside conditions, and is an ideal temperature for the organ—which is one of the largest (if not the largest) in England.

Another remarkable feature is the thermal storage of the structure, for it is found that if the oil furnaces are turned off, it takes 36 hr for the temperature in the cathedral to fall 1 F. It has been found in actual operation throughout the winter, that if the fires are operated for a few hours only each day, the temperature change is so small it cannot be detected on the thermometer, regardless of any change in the outside temperature.

A Hospital System

Another illustration shows a similar system applied to buildings having several floors; this is an actual system installed in a large hospital. The construction of the underfloor is concrete as described above, but the warm air ducts in the floor with this system were made about 4 in. deep, which is quite sufficient because of the smaller amount of air carried. The covering over the ducts is constructed in concrete 1½ to 2 in. thick, sometimes cast over solid and sometimes laid in slabs. If a hardwood floor is to be laid as is invariably the case with hospitals, wood dovetail sleepers are secured in the concrete as it is cast, to which the boards can be secretly[1] nailed. Provided the wood sleepers and the top floor boards are well seasoned, there is never any trouble due to the heat. Teak has been used very extensively for this particular purpose, although wood blocks have been used on many occasions with great success. In fact, it

*Chief Engineer, Sarco Co., Inc.

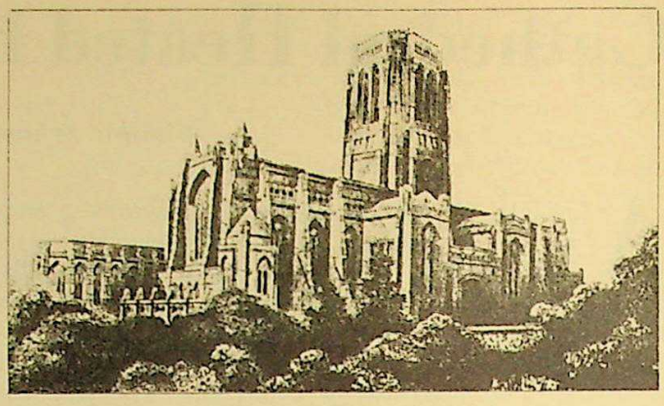
[1]The nails are driven in sideways between each board so that no nails are seen from the surface.

is possible to use any composite floor, provided no material such as bitumen, which will become plastic with the heat, is used.

Hollow tile floors—as indicated in the sketch—have been found well adapted to floor and ceiling heating systems.

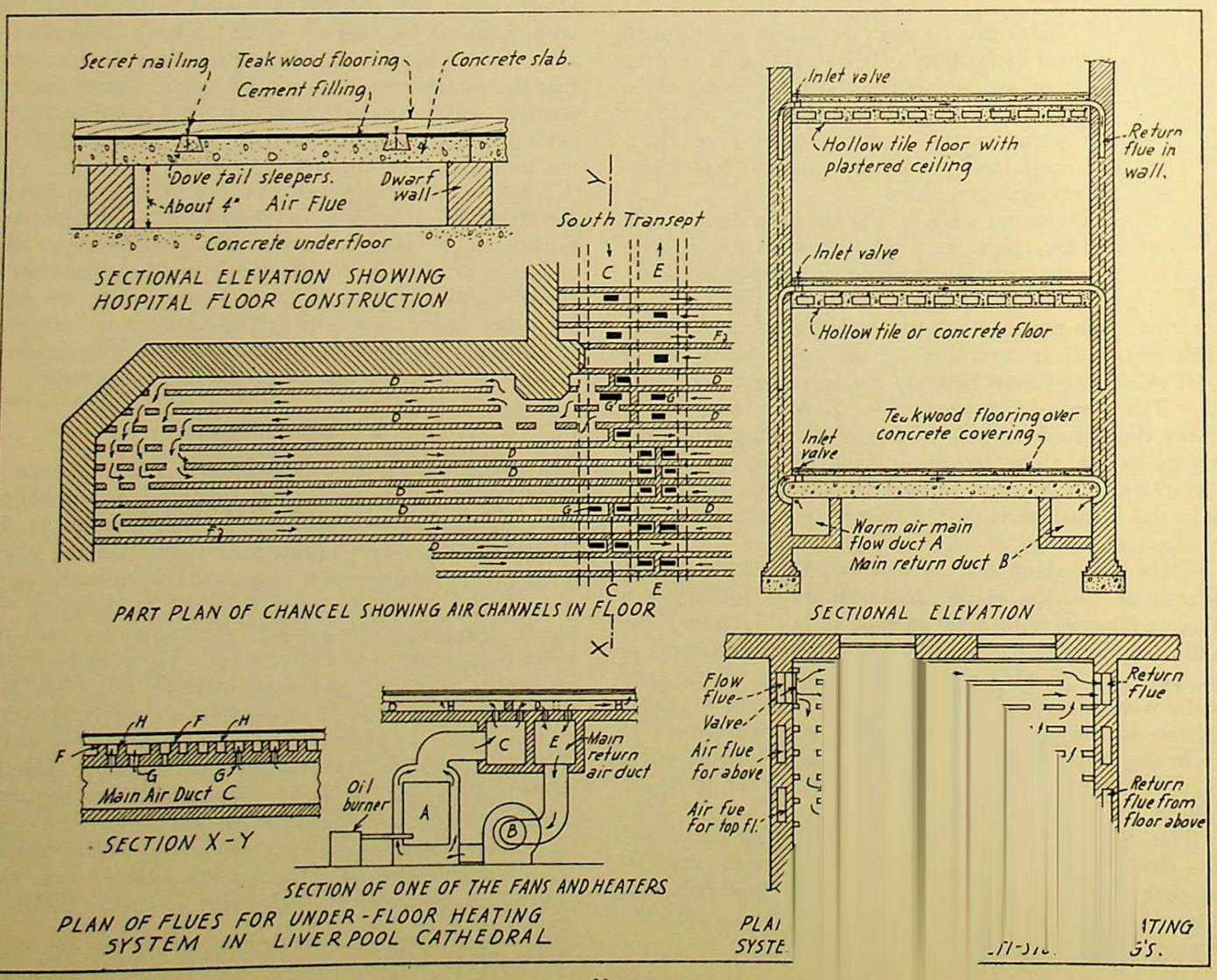
It will be noted the main flow and return ducts are formed under the lower floor with vertical ducts formed in the walls whereby a circulation of warm air is maintained to the various rooms. A valve or damper is installed at the opening of the duct to each room so that the amount of warm air to each floor space can be regulated and controlled. When the main ducts are constructed in the soil as shown, it is necessary to have these lined to prevent moisture being drawn in from the adjacent soil; otherwise there is a danger that the moisture absorbed by the hot air will saturate the air in the floor space and cause it to give up this moisture to the cooler surfaces in the floor. If this happened it would find its way through the concrete of the upper floors on to the ceiling below.

In hospital operating amphitheaters where the temperatures are necessarily higher it is customary to pass the air through channels formed in the walls as well as the floor and sometimes in the ceiling. By constructing such a room with white marble slabs covering the ducts in the walls and floor, an ideal sanitary finish is obtained which can be washed and kept perfectly clean. With such a system the whole floor area can be left free for instrument stands and other equipment.



Liverpool Cathedral

The effect of radiant heat with a slightly cooler air temperature is ideal for the surgeon to operate, while the entire absence of air currents, with a moderate and constant stream of heat rays, presents a much safer condition to the exposed organs than is possible with any system where air currents are created. Any slight movement of air in an operating room, with the air coming from heated surfaces which may not be scrupulously clean, is likely to carry germs and deposit them on the exposed organs of a patient.



Panel Warming and Cooling

Consulting Engineer Describes Installation in School

By Erwin L. Weber*

AMONG other innovations, the recently completed high school, civic auditorium and gymnasium building at Everett, Wash., contains an installation of panel warming and cooling. The building is one of a group, comprising the high school on the west side of Colby Ave., and on the east side, the vocational building along 24th St., the commercial building along 25th St., and the new building in the middle of the block between the latter two buildings. The central heating plant supplying the group is situated in the vocational building.

The new building is 254 ft long and 167 ft wide. The main body of the building consists of the foyer on Colby Ave., which leads to the auditorium with 1550 seats and to the balcony with 663 seats, the north and south entrances and stage in the center portion, and at a continuation of the stage level, the gymnasium, which faces on Wetmore Ave. The gymnasium bleachers will accommodate 1426 people. This makes a total seating capacity of 3639, which may be increased to about 4400 by providing chairs on the gymnasium floor. The gymnasium and stage are separated by a soundproof folding door 43 ft wide by 16 ft high. Another motor operated folding door permits the axial division of the gymnasium into girls' and boys' sections.

Heating and Air Conditioning System

A fresh air plenum space extends under the auditorium and also under the balcony. The cafeteria is under the gymnasium and the plenum chamber and kitchen are situated under the stage.

Fresh air passes through a 16 ft by 10 ft air washer with two sets of atomizing nozzles. In lieu of tempering coils, the water in the washer is warmed by a steam jacketed converter set for 53 F dew point control. The air then passes through heating coils set for 65 F dry bulb temperature. A multi-speed, motor driven, double inlet, double width fan of 80,000 cfm capacity forces the air into the plenum chamber, which is acoustically treated both on the floor and on the walls and ceiling.

The air then passes from the plenum chamber through individual reheating coils to the various sections of the building which require ventilation; namely, middle right, middle left, outside right, and outside left auditorium; right and left balcony, right and left gymnasium bleachers, and right and left cafeteria. Each of the coil discharge casings is provided with an intermediate acting, remote controlled shut-off damper. A duct with "superheating" coils supplies air to the foyer, where a switch gives the doorman remote control of the steam admission to the coils.

Steam at 125 lb pressure is brought underground from the boiler room to supply the converter, heating and reheating coils, stage radiation, kitchen equipment and the unit heaters in the gymnasium.

Due to the cool summers on the northwest coastal strip, no cooling means other than the evaporative cooling effect of the air washer is required.

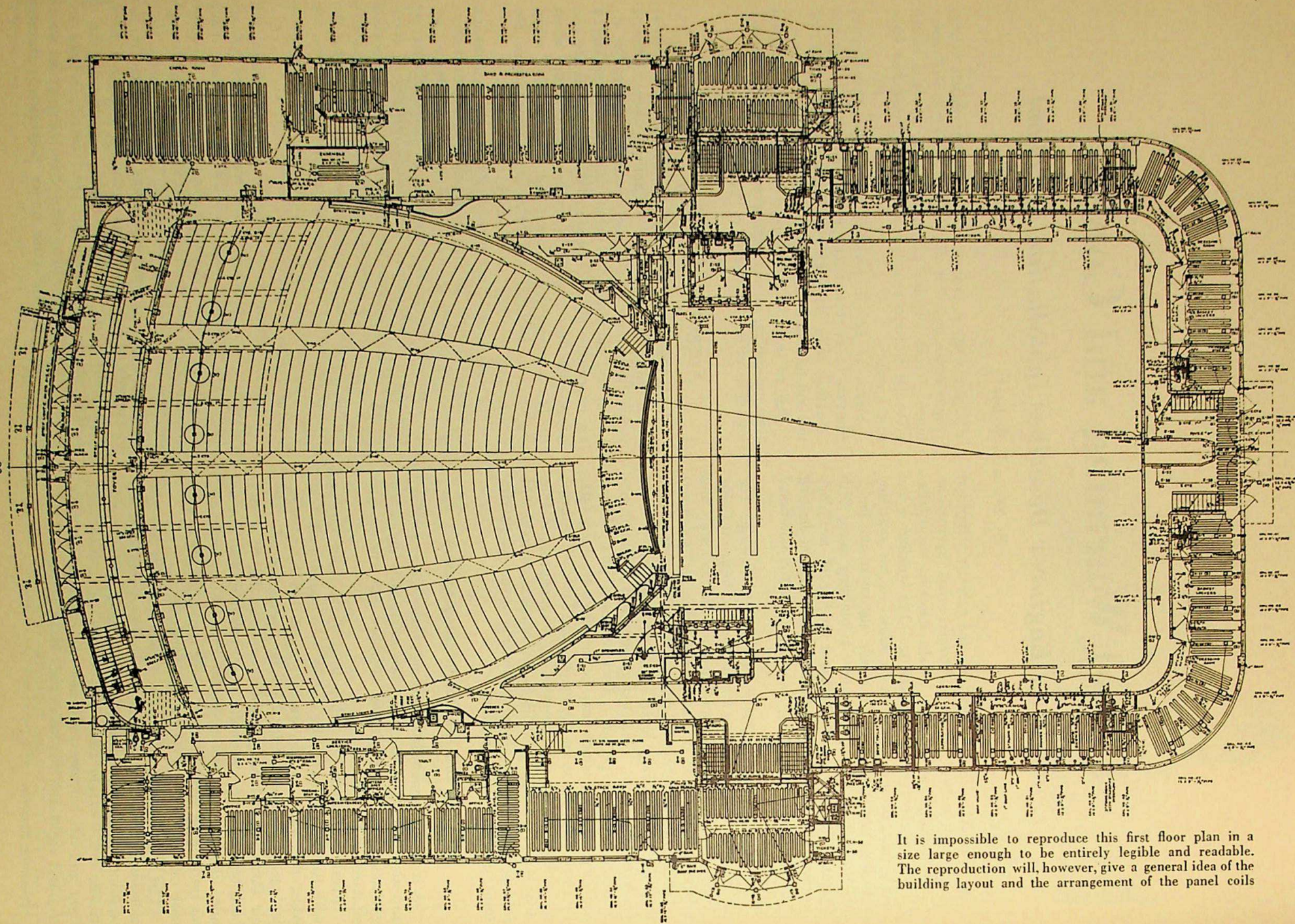
Temperature Control for Auditorium

When people are seated close together, as in a theater, a lower air temperature is required when the house is full than when it is sparsely occupied, due to the effect of heat radiation from person to person. According to my experience, the most comfortable conditions are obtained with the air at 69 F dry bulb temperature when the house is sparsely occupied and 65 F to 66 F when the house is crowded, with intermediate temperatures for intermediate degrees of occupancy.

The coils to the auditorium, balcony and gymnasium bleachers are controlled by intermediate acting duct thermostats situated in the various branch ducts where they are naturally not readily accessible for frequently setting the control temperatures for various degrees of occupancy. Hence, remote controlled adjustable thermostats were used in these ducts. A control board is conveniently situated in the fan room, with switches for setting the remote controlled adjustable thermostats in the two top rows and switches for the remote controlled dampers in the two bottom rows.

Upward ventilation is used in the auditorium and balcony. Air is introduced under alternate seats through ventilators especially made for this installation. Each deflects the air toward the floor to assure low velocities and freedom from drafts. Vitiated air passes through grillages in the plaster ceiling to the attic space, from where it passes through insulating board ducts to the exhaust fan room which has acoustically treated floor, walls and ceiling. A double width, double inlet fan of 35,000 cfm capacity discharges the vitiated air from this room. Here are also situated a second exhaust fan which removes air from the soffit under the balcony through

*Consulting Engineer.



It is impossible to reproduce this first floor plan in a size large enough to be entirely legible and readable. The reproduction will, however, give a general idea of the building layout and the arrangement of the panel coils

outlets built into the electric fixtures and a third exhaust fan which removes air from the toilets.

Gymnasium and Cafeteria

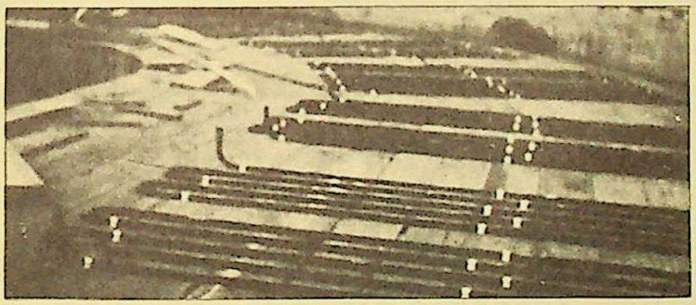
The main body of the gymnasium is warmed by four unit heaters. Air is supplied to the spaces under the bleachers and is diffused through slots in the risers. This makes it possible to supply air to the bleachers suitable for the spectators, while the body of the gymnasium is kept cooler for the players.

The cafeteria is supplied with air through grilles situated along its entire perimeter near the ceiling and all air is exhausted through the adjoining kitchen.

On the north side of the auditorium are the school board offices and on the south side are the music, choral and band rooms. All around the gymnasium, under the bleachers, are the shower rooms, dressing rooms, locker and other gymnasium auxiliary rooms. This group of rooms is one story high with concrete floors laid directly on the ground.

Panel Warming for One Story Section

The former offices of the school board were situated on the first floor of the high school building and, having no basement under them, the floors were often disagreeably cold. The school board was concerned about having warm floors in their new quarters and was considering



Construction view showing coils on form

various items, such as a rifle range, etc., to establish an excuse for building a basement. The boiler plant was also insufficient to supply all the heat requirements of the group and no funds for plant enlargement were available. To assure warm floors without the use of a basement and to make the best use of the existing boiler capacity, it was decided to use panel warming for this group of rooms in the single story section of the building and to install a 4000 gal capacity hot water storage tank in the boiler room to supply the gymnasium showers and heat for the panel warming system.

In panel warming systems, the radiant rays from the ceiling impinge upon the floor and there produce heat, in the same way that the sun's rays heat the ground and other surfaces.

Hot water from the storage tank is mixed with cold water through a thermostatically controlled mixing valve to give a resultant tepid water supply at 115 F. This is used as the normal hot water supply to the showers and together with a cold water supply is connected to each individual shower mixing valve. This avoids possibility of scalding and permits the storage water to be heated above the boiling point. The panel warming system is designed for a maximum water temperature of 130 F.

The 4000 gal of water in the storage tank can be heated to 220 F in 1½ hr and will supply the panel warming demand at full load until the water drops to 140 F, thus giving a heat storage capacity of $4000 \times (220-140) \times 8.3$ or roughly 2,600,000 Btu. The panel warming system has a heat transfer capacity of about 550,000 Btu per hr. Hence, it may be operated during cold weather for nearly 5 hr from the storage tank, or the panel warming system and gymnasium showers may be operated together for over 3 hr from the storage tank, without placing any demand upon the boilers.

The water for the panel warming system is heated in a countercurrent flow converter which has a capacity of 1,000,000 Btu per hr when heating water from 115 F to 130 F, while being supplied with water from the storage tank at 140 F. It contains 250 sq ft of heating surface made of copper tubing. The converter is also provided with a cold water connection for cooling the panel system by means of city water during the summer. Neither the water from the hot water storage tank, nor cold city water, is circulated through the panel system as the continuous introduction of new water introduces air into the system and may cause scaling or pitting of the pipe.

A motor driven centrifugal pump with a capacity of 135 gpm at 30 ft head circulates the water in the system through four thermostatically controlled zones; offices, music rooms, girls' gymnasium and boys' gymnasium. The flow water to each zone is derived through a three way diaphragm mixing valve, supplied with flow water from the converter and with return water from the pump discharge, wherein it is mixed to the temperature demanded by the room thermostat of each zone. The common return enters the suction inlet of the pump.

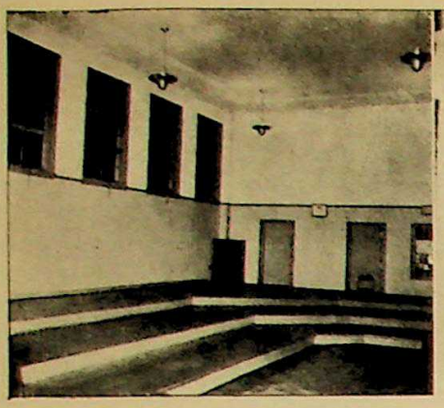
11,000 Ft of Pipe for Coils

The panel coils contain nearly 11,000 lineal feet of ½ and ¾ in. steel pipe bent on 6 in. centers. All joints were welded and tested to 500 lb air pressure under water and a steel ball was blown through each coil to assure the absence of "inside welds" or other obstructions.

The coils are embedded in the concrete ceiling slabs in all the gymnasium auxiliary rooms. The soffits were finished with three coats of plaster work, with a scrim embedded in the last coat. The offices and music rooms all have furred ceilings and the coils are wired to 1¼ in. pipe battens hung from the roof slabs. The first coat of plaster was carefully "pushed through" the metal lath to give an intimate contact with the coils. A second coat of plaster was next applied and in the third coat of plaster, a scrim was embedded while the plaster was being "floated on."

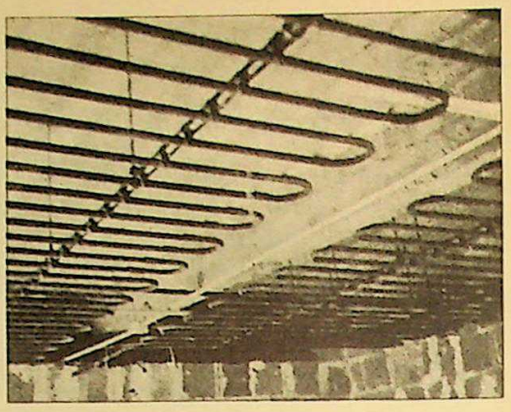
The flow and return mains are run in the space above the coils. A supply branch to each room drops down in the inside partition, is provided with a shut-off and drain valve and then rises to supply the panel coils, which discharge individually to the return main through an equalizing non-reflux elbow.

The panel warming system has been in operation since



Music room

Board room



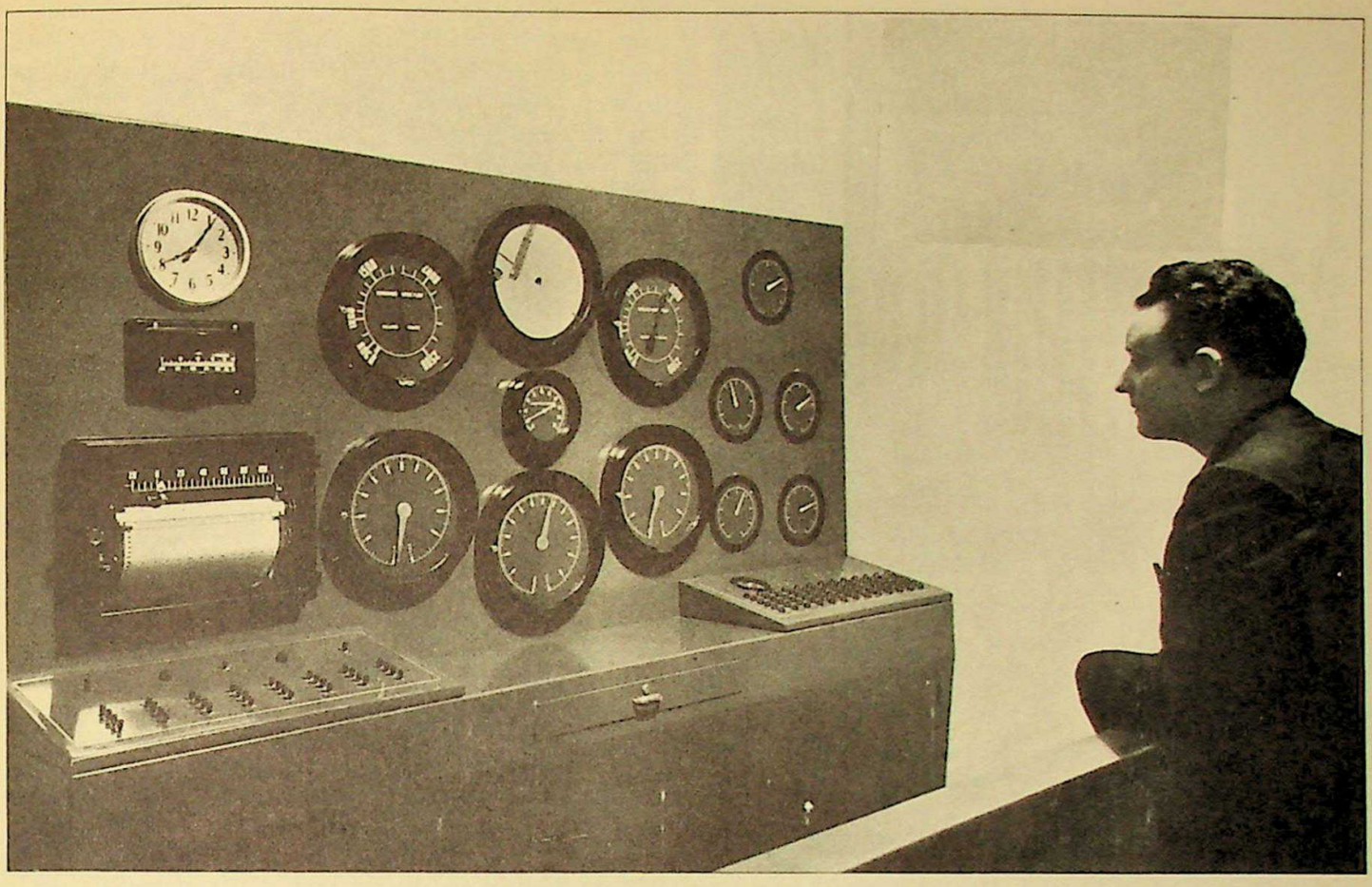
Construction view showing ceiling coils

last September and has given excellent satisfaction. The floors, walls and windows have a notably higher surface temperature than in conventionally heated rooms.

The system is to be used for cooling the offices this summer, as city water is economically available at 62 F, and as the dew point temperature of the outside air never exceeds 60 F, condensation should not form on the ceiling. As the dry bulb temperature of the air seldom reaches 90 F, a considerable and sufficient "panel cooling" effect should be attained without the use of mechanical refrigeration.

The building was designed by Earl W. Morrison, Architect, and the electrical, mechanical and sanitary equipment was designed by the author. I. G. Navarre Plumbing & Heating Co. installed the mechanical and sanitary equipment.

The panel warming and cooling system was licensed from Richard Crittall & Co., Ltd., of London, through Wolff & Munier, Inc.



The Bankers Life building superintendent looks over his control board. Selector switches on the panel at the lower left enable him to get readings on the electrical thermometer (directly beneath the clock) of temperatures at key points in the apparatus and at 24 stations throughout the building. A six point recorder immediately above this panel charts the trend of various conditions affecting operation. The panel at the lower right contains a master thermostat and pilot lights for the various items of equipment — fans, spray pumps, compressors, radiant heaters, booster heaters, boilers and air cleaner. The center of the board contains a combustion recorder and dials indicating header steam pressure and the fuel supply, and flow meters for water

Wall Warming System Complements Air Conditioning of New Building

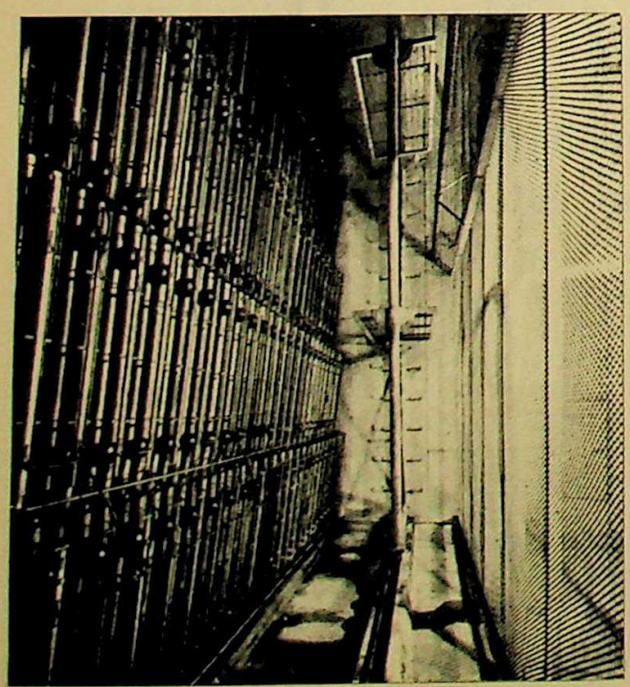
Bankers Life Builds Home Office Building With Noteworthy Features — Air Conditioning an Integral Part of Design

A UNIQUE wall warming system that works as a complement to the air conditioning and is designed to make every square foot of floor space comfortable and usable—right to the exterior walls—is a feature of the new home office building of the Bankers Life Co., Des Moines, Iowa. Called by a leading architectural magazine "the building of the decade," the structure is noteworthy in many respects.

Tinsley, McBroom & Higgins were the architects and the consulting engineer was Charles S. Leopold.

The wall warming scheme used should not be confused with "radiant heating," although in some respects its objectives are the same. Radiant heating is generally used to describe a type of heating system in which the ceilings, floors or walls are heated to a degree that will permit comfort of the occupants at a general room temperature substantially below present accepted standards. In systems of this type the heating pipes are usually embedded in the building material and the building surface raised to temperatures in excess of 100 F. In the Bankers Life building it is necessary to heat the wall only to a temperature at which the average radiating temperature of the windows and outside walls will limit the rate at which the body loses heat by radiation, and to approximate the average radiating temperature of interior walls, floor and ceiling; the required tempera-

The new $2,000,000 home office building of the Bankers Life Co., Des Moines, Iowa, offered a number of interesting air conditioning and heating problems, and the solutions were equally noteworthy. As this photo shows, the building consists of six principal floors, a ground floor, and a partial seventh floor. There is also another basement below the ground floor. Windows throughout are double glazed, and with the exception of those on the sixth floor, are set in panels of glass block. The cooling tower was constructed as a part of the structure with only the inlet louvers visible from the outside. The building has many features



The electrostatic air cleaner installation. Especially effective in removing smoke particles, this device gives to all foreign matter carried in by the air from outside a positive electrical charge. Small platinum wires running lengthwise along both sides of each unit carry a 13,000 volt charge for this purpose. Then the air passes between two metal plates, one charged positively with 6000 volts and the other negatively charged and grounded. As the air passes through the electrostatic field thus set up, the positively charged dirt particles are repelled by the positive and attracted by the negative plate. Trapped on this plate, they are permanently removed from the air supply and the 550 Bankers Life employees can do their work more healthfully and efficiently as a result. Spun glass filters in the recirculated air assist in removal of dirt

ture is thus in the vicinity of 70 F. With this installation, local sensations of warmth or coolness from interior partition to outside wall are practically eliminated.

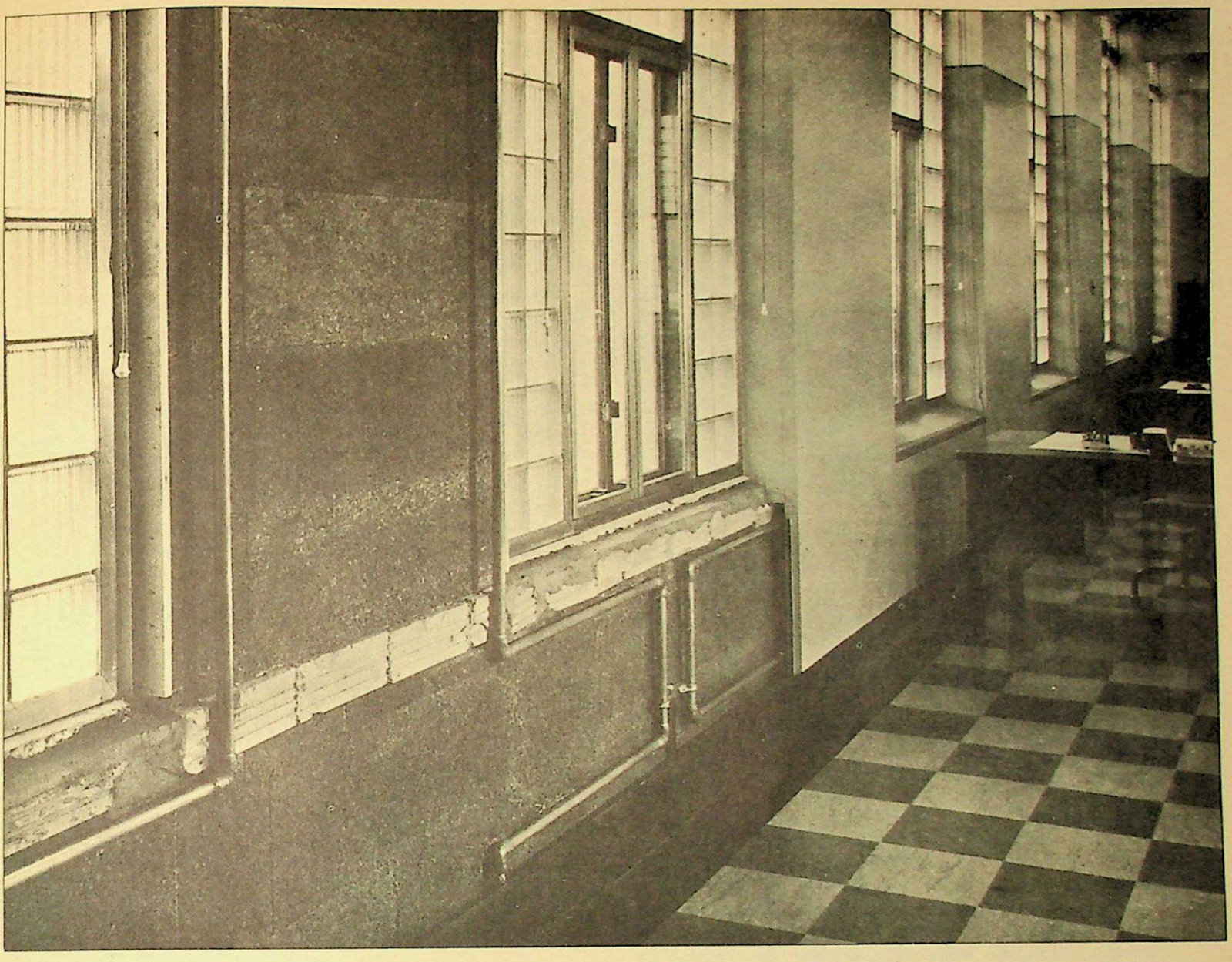
In this connection, the wall construction of the building plays an important role. In the clerical areas on the five principal floors, factory-enameled steel panels are used. Behind these wall panels the entire building is insulated by a 2 in. layer of cork. Between the cork insulation and the sectional steel panels, a system of 1 in. bare copper tubes loops around and under the window openings. In winter hot water will be pumped through the tubes to balance heat loss through the double windows and the cork insulation.

Although the air conditioning system is capable of heating the structure, in a cold climate such as Des Moines it is usually desirable to provide separate means of heat adjacent to the window and wall areas in order to counteract the cold sensation due partly to the descending current of relatively cool air directly adjacent to the wall or glass surface, and partly to the sensation of cold caused by the body radiating heat directly to the cold surface. In the design of this building, unusual effort was made to make the working spaces completely usable, as reflected (for instance) by the elimination of columns. This same thought was extended in the selection of the perimeter warming system and it was desired to eliminate concentrated sources of heat directly adjacent to the windows as well as the grilles and openings which would be required for convection radiators. The fact that it had been determined to insulate the outside walls and that there would be a space between the inside and outside walls (whether the interior wall was to be of plaster or metal) aided in the solution of the problem from the standpoint of cost in that no additional construction was required and heat loss from the relatively warm space to the outdoors was greatly reduced.

Use of this space around the perimeter of the building adds 8 per cent to the total useful floor area. The elimination of columns permits a further increase of more than 12 per cent. Consequently the architect in charge, Leland A. McBroom, estimates that the company would otherwise have had to add another entire floor to the building in order to furnish equivalent working space. This is one of the savings achieved in the building by taking the long-run point of view.

With the wall and window heat losses supplied in this manner, the air delivered by the conditioning system will vary from room temperature downward, even in the winter. The wall warming system will also be used during the winter when the building is not occupied and will serve to keep the building at the proper temperature so that the minimum time will be required to reach proper conditions in the morning. The wall warming system was essentially designed for winter service but has been equipped so that chilled water can be circulated in hot weather.

Check of wall and window temperatures was made by thermocouple at a time when the air conditioning system was not in operation. The widest difference in temperature of the wall from floor to ceiling was three degrees, the highest temperature occurring directly beneath the window.



In the left foreground several of the sectional steel wall panels have been removed to show the 1 in. bare copper piping of the unique wall warming system. This piping carries hot water under forced circulation, balances any thermal losses through the windows and the 2 in. layer of cork insulation which lines the exterior masonry walls throughout the building. Unlike radiant heating as it is generally known, the Bankers Life wall warming system maintains wall and window temperatures of 70 F

Double glass windows are used throughout the building. With the exception of the sixth floor, all windows are set in panels of glass brick. This frame of glass blocks is shaded so far as possible by projecting piers, so that radiant heat stored in the blocks will be reduced. At the north side of the building glass brick is used to a greater extent, since the problem of sunlight and radiant heat is eliminated there.

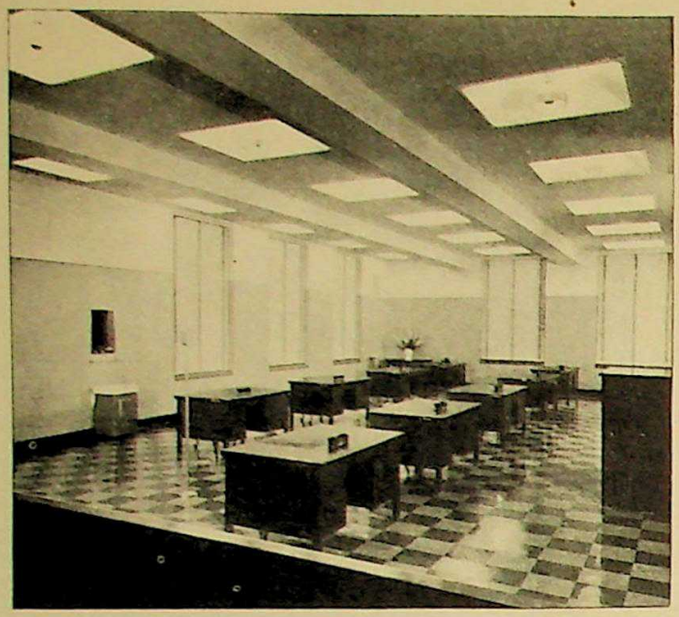
Air Conditioning an Integral Part

In the design of the building, the air conditioning was incorporated as an integral part of the structure and the architect therefore could take advantage of it in the building design. Window and glass areas were selected to meet the need for daylight without having to consider natural ventilation. The air conditioning system thus is vital to successful operation of the building in all seasons.

SUMMARY

A unique wall warming system, comprising copper piping through which hot water is circulated, is one of the numerous features of the new home office building of the Bankers Life Co. at Des Moines, Iowa. Not to be confused with "radiant heating," object of the wall warming is to maintain exterior wall and window surfaces at about the same temperature as interior wall, floor and ceiling surfaces, thus make the entire floor area right up to the exterior walls usable. The architect estimates that use of this space around the perimeter adds 8 per cent to the useful floor area. Elimination of columns permits a further increase of 12 per cent. Thus, the company would otherwise have had to add another entire floor in order to furnish equivalent working space. . . . . Total capacity of the refrigeration plant for summer air conditioning is 650 tons. The air conditioning is completely zoned, and there is an elaborate control system to promote economical and satisfactory operation. . . . . The heating and air conditioning of this structure, which has been called "the building of the decade" by a leading architectural magazine, is described in some detail here

Two main conditioned air fans and the fan used for return and exhaust are situated in the pent house adjacent to the elevator equipment. The duct distribution of conditioned and return air is substantially vertical through the utility shafts of the building. In the gen-



This is part of a typical workroom. Uniformity of air distribution through the perforated metal acoustical ceilings and uniform light distribution from the pressed steel coffers recessed in the ceilings make it possible to re-arrange desks or whole departments at any time in the future as the life insurance company's varying needs require. There will be no occasion to revamp the duct work, the lighting fixtures or the rubber tile flooring. This is one of the many illustrations of foresight on the part of the building committee, the architect and the consulting engineer. It is interesting to note that the acoustical material in the ceilings was placed on the under side of the slab of the floor above to limit transmission of heat through the floors and simplify access to the piping and mechanical equipment within the ceilings

eral work areas the system is controlled in accordance with zones corresponding to the sun exposure and the air is delivered through perforated ceilings. The ceiling construction differs from the usual in that the sound absorption material was placed in the under side of the slab of the floor above. This method was selected in order to limit heat transmission through the floor and to make the systems less dependent on the tightness of plenum spaces, as well as to provide easy access to various piping and mechanical equipment situated within the ceiling.

Individual control of temperature is provided for the private offices on the sixth floor by means of booster heaters in the individual air ducts. Air delivery in this area is upward at a slight angle from the window sills. A portion of the basement is air conditioned by a separate coil surface unit and rough storage space in the basement is ventilated but not conditioned.

The main exhaust fan at the seventh floor draws air from various floors and automatically discharges it outdoors or back to the conditioning apparatus, as required. Air from outdoors, together with a portion of the return, passes through suitable preheaters and then through an electrostatic precipitator where from 85 to 90 per cent of all dirt is removed. This equipment was selected to remove smoke particles, which cannot be effectively removed with ordinary filters, as well as the air borne dirt and pollens usually present. The 182 cells of the precipitator have a total capacity of 124,000 cfm of air.

The outside and return air mixture passes through an air washer where moisture is removed or added as required. In the summer, cooling is simultaneously effected. Copper was used in the construction of this air washer in view of the importance of continuity of service but it was not considered necessary to use copper for the washers in the auditorium and basement systems. The treated air leaving the washer then passes directly to the main supply fan and to the fan on the south zone system. The main supply fan unit supplies treated air to seven local recirculating fan units, in which the conditioned air and filtered, local recirculated air are mixed to form the total supply for the particular zone served. In all there are 22 fan units for supply and exhaust.

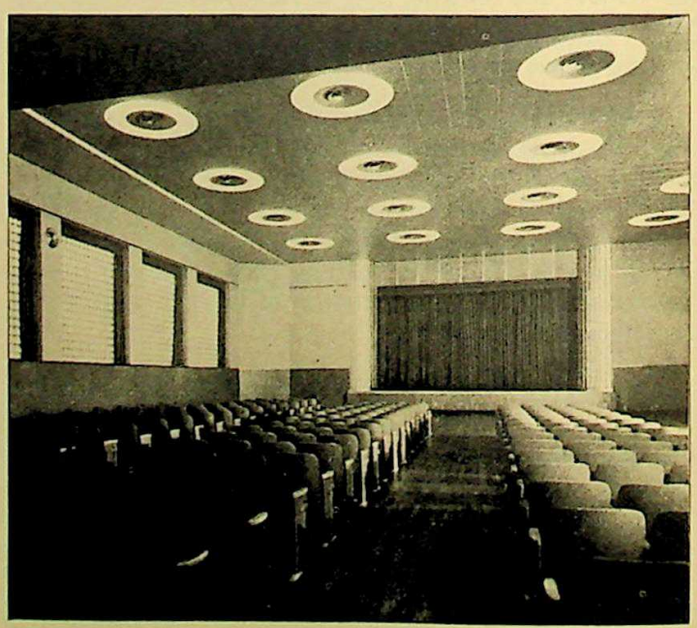
Refrigeration is provided by three "Freon" compressors—two 4 cylinder, 260 ton and one 2 cylinder, 130 ton machines—which are driven by 4000 volt synchronous motors of 300, 300 and 150 hp. Each of the four cylinder machines is directly connected to its own evaporator and condenser and the two cylinder machine may be used in conjunction with either evaporator and condenser unit. By opening suitable valves the entire plant may be made to operate as one unit. Thus the failure of any one piece of equipment would not seriously impair the functioning of the building. Heavy equipment in the machine room is insulated against vibration and noise by floating foundations and isolators utilizing cork.

The compressors are connected with equalizing lines and a special automatic system for controlling the oil returning with the suction gas.

The compressors discharge through pulsation tanks into a pair of horizontal multipass shell and tube condensers, each 34 in. in diameter and 17 ft long, which are equipped with tubes of admiralty metal. A purger saves both power and refrigerant. There are also two receivers, each 24 in. in diameter and 16 ft long, and two spray type water coolers, 42 in. in diameter and 12 ft long. Connected to the coolers are "Freon-12" liquid pumps of 4 in. size, as well as the necessary filters and float valves.

Capacity controls on each cylinder of the compressors permit reduction of the output of any one machine in steps of 87½, 75, 62½, and 50 per cent.

In the auditorium, seating 1100, 6 ft ceiling coffers provide for the reflection of light and for the installation of high velocity air diffusers. There are 24 of these coffers. The auditorium is used for employee meetings, salesmen's schools, and similar purposes



Complete Control Installation

The control desk and switchboards in the compressor room govern the operation of the air conditioning and wall warming systems. Three panels at the left control the compressor motors, with dials on each panel indicating the direct current amperage, power, and alternating current amperage. Three panels at the right control the chilled water and condenser water pumps and auxiliaries.

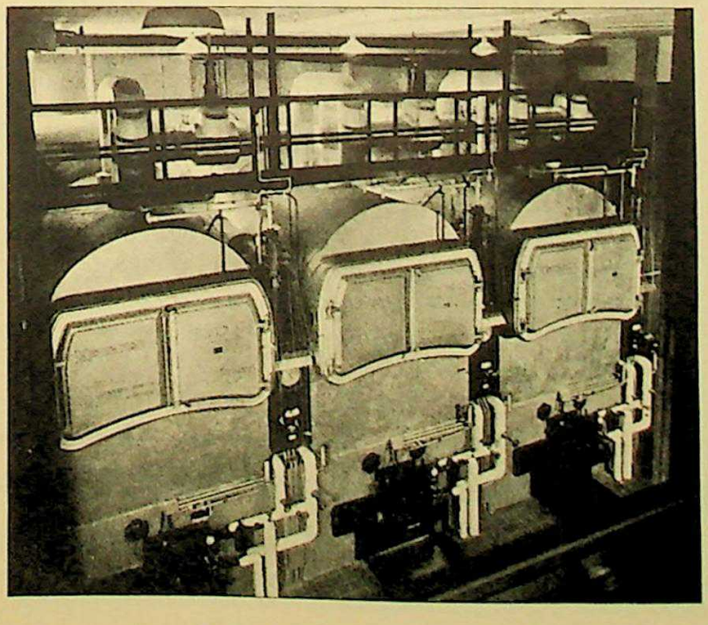
The center control section contains a panel at the lower right for the control of the following equipment: Fans, spray pumps, compressors, radiant heaters, booster heaters (for the individually controlled sixth floor system), boilers, and electrostatic air cleaning apparatus. Alongside the units on this panel are pilot lights and start and stop buttons. A master thermostat is situated at the top of this panel.

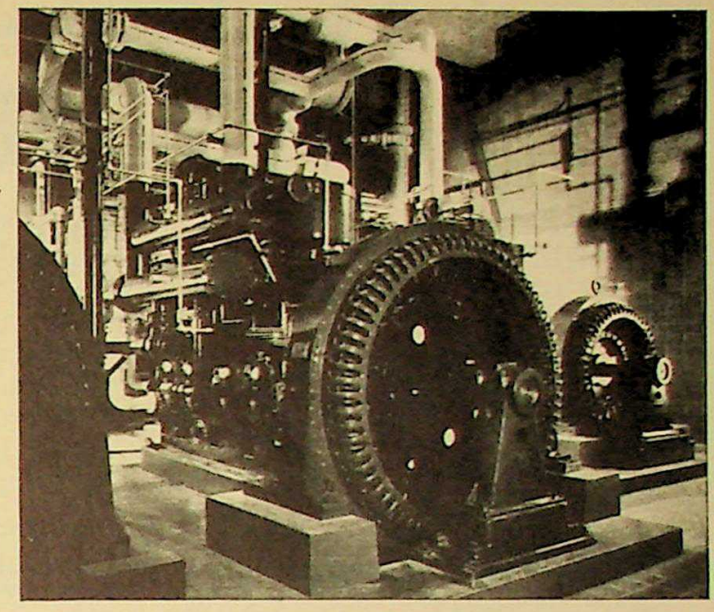
In corresponding position on the left another panel contains selector switches which enable the operator to check temperatures at key points in the apparatus and at 24 stations throughout the building. These temperatures are indicated on an electrical thermometer at the center of the control desk. This gives the operator instant and exact information at all times as to the needs of various parts of the building and just how well those individual needs are being supplied.

In this connection, it is interesting to note that the heating and air conditioning system is divided into four major zones on each floor—north, south, east, and west. Each of these zones is subject to independent thermostatic control, and this zone system allows for variations in outside temperature due to sun or prevailing winds.

The controls that govern the temperature of water through the radiant system (actually four separate systems) automatically adjust for the required temperature in each zone, in direct relation to the exterior conditions to which the zone is exposed. Similarly, the four duct supply systems are controlled automatically for humidity and temperature.

This battery of three low pressure oil burning boilers supplies the heat requirements. Rated at 185 hp each, they provide 50 per cent more capacity than the maximum expected at any time





This view shows the compressor units. The two larger compressors can be seen in the foreground and the smaller one at the right. Total capacity is 650 tons, with the larger units supplying 260 tons each and the smaller unit 130 tons. Powered by 4000 volt, 300 hp synchronous motors, the large compressors are directly connected to their own evaporators and condensers. The 130 ton compressor may be hooked up with either evaporator

Above the electrical thermometer on the control board is a recorder which keeps a running record of the following temperatures: Outside wet bulb, outside dry bulb, apparatus dew point, fan discharge and return air. The recorder was selected for these points since the trend, in addition to the momentary value, is helpful in operation. On either side of this recorder are the flow meters for condenser water and chilled water.

With the exception of the start and stop buttons for operation of the equipment, all these controls are repeated on a similar board in the building superintendent's office. In addition, his board contains a combustion recorder and dials indicating the fuel oil supply in the three storage tanks, which have a combined capacity of 16,500 gal.

The building superintendent keeps a daily log covering all conditions in the air conditioning and heating system and all conditions affecting the system. A total of 57 entries is made on this record every 2 hr.

In addition to the daily log and in conjunction with it, the superintendent prepares a daily metering record. This covers all energy, fuel and water consumption, together with the basic operating conditions during the period covered. These records will enable the company to keep an extremely accurate check on operating costs and on the best methods of handling the system for cost control.

The boiler room contains three boiler units burning bunker C oil under complete automatic control. Each boiler is provided with an operating panel showing pressure, over fire draft, and the degree of smoke. Combustion recorders for the three boilers are mounted on a separate panel. In the superintendent's office there is an instrument to indicate the smoke of the total chimney and an alarm to notify him of any objectionable smoke condition.

Photos by Hedrich-Blessing Studio

Panel Heating— with WARM Well Water

KLAMATH FALLS is situated in southwestern Oregon near the California border, and lies in that portion of the Cascade mountain range extending between Crater Lake—a beautiful lake in the crater of an extinct volcano—and Mount Lassen, the only active volcano in the United States. This entire strip of mountains is of volcanic origin. Underground lakes of hot water are frequently found here and supply many hot springs, or they may be tapped by drilling a well. Such a lake exists under the City of Klamath Falls, where many hot water wells have been drilled and the water used for heating purposes by employing low temperature radiators and convectors, or blast heaters with fans.

Engineering may be defined as utilizing natural resources to the best advantage; the service and repair garage at Klamath Falls, Ore., which is described here is a pertinent example. Underground lakes of hot water in this volcanic region may be tapped by wells and the water used for heating. The well serving this garage is 490 ft deep and at the 475 ft level the water temperature is 145 F. . . . This water is used in a panel heating system. In the garage area, floor coils are used in order to warm the floor and create comfortable and efficient conditions for the men working under snow covered and ice caked cars. In the office portion, the pipe coils were placed in the suspended plaster ceiling. . . . The well has a 3 in. pipe extending down into it, and a 2 in. return riser enclosed in a 4 in. pipe with insulation between the 2 in. and 4 in. pipes. The water is warmed as it descends in the 3 in. pipe and is prevented from recooling as it rises in the insulated 2 in. pipe. . . . The method of heating the water is therefore unique and couldn't be applied in very many cases. However, the panel heating system could be utilized with water from any source

Last year the Specialized Service Co. built a service and repair garage. The building is 50 ft wide by 150 ft long and has a concrete floor pitching toward the rear of the building. The walls are 8 in. tile and the roof is of the open truss type with only sheathing and roofing material on top. In the left front are offices with a suspended ceiling having several skylights, and a storage basement is built under the offices.

On the site was a 10 in., 490 ft well with casing extending down 125 ft. The upper water level is about 30 ft below ground level and the water has a temperature of 60 F. A pumpage of 25 gpm for 72 hr showed a drop in water level of only 27 ft with a slight increase in water temperature. At a depth of 150 ft the water has a temperature of 104 F and this temperature gradually increases to 145 F at a depth of 475 ft. Calculations showed that it would be possible to get a water temperature in the heating system of nearly 120 F and that it would be feasible to use this well and secure very comfortable conditions in the garage at a very low cost and without the use of further insulation in the walls and roof by the use of panel heating.

Water Heated in Well

The "heating plant" consists of a 3 in. pipe extending down in the well to a depth of 450 ft and a 2 in. return riser enclosed in a 4 in. pipe with insulation between the 2 in. and the 4 in. pipes. The panel heating water is warmed as it descends in the 3 in. pipe and is prevented from recooling as it rises by the insulation over the 2 in. pipe. It is circulated by a 1½ in. centrifugal pump with a capacity of 40 gpm at 50 ft head, driven by a 2 hp motor.

During the winter cars entering the garage are usually caked with ice and snow, and men working under them on a cold floor feel very uncomfortable and cannot work efficiently. To counteract these conditions, the panel heating coils were placed in the concrete floor in the garage. In the offices, which have a storage basement under them, the coils were placed in the suspended plaster ceiling.

The Pipe Coils

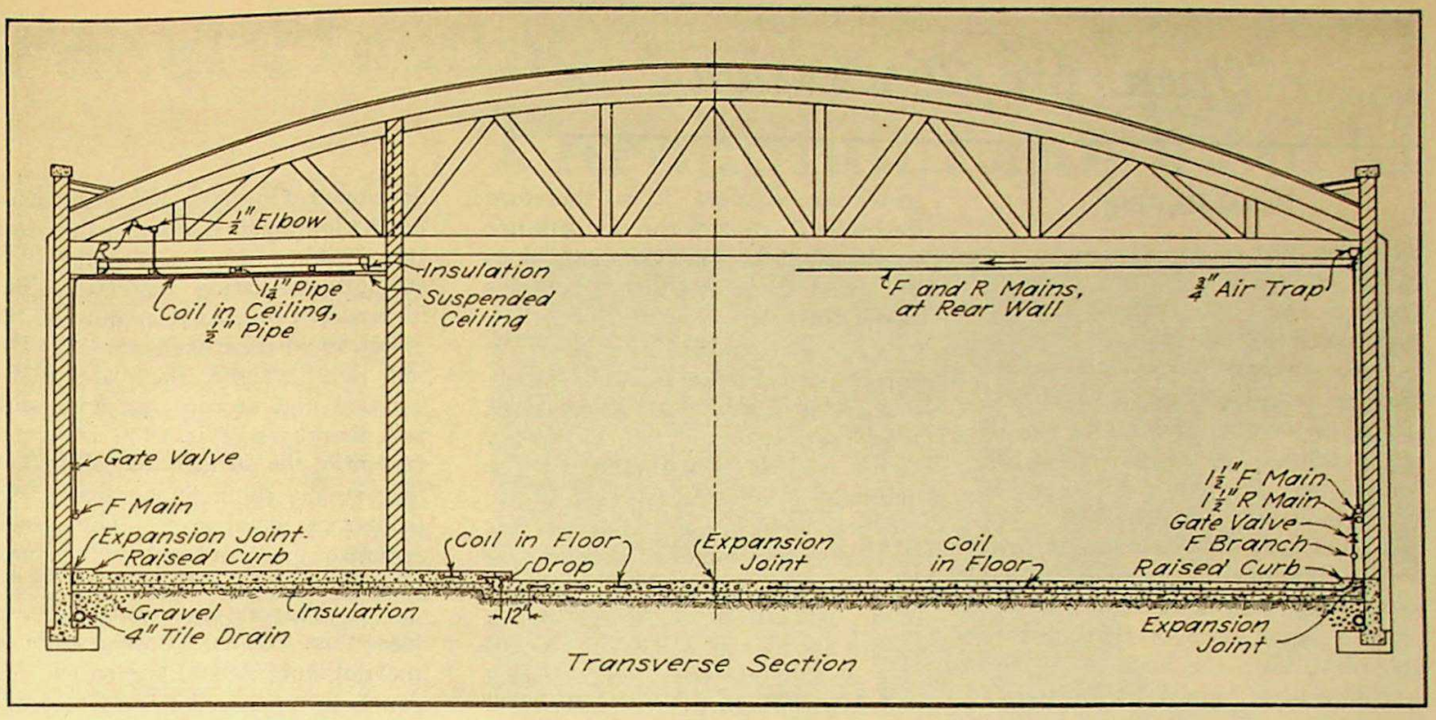
The panel heating system comprises about 9000 lineal feet of pipe coils. Expansion joints divide the floor into bays 25 ft, 0 in. by 18 ft, 9 in. Each bay has an independent group of two or three coils connected in multiple and supplied with a shut-off valve on the flow connection and an equalizing non-reflux elbow on the return end for balancing the system and avoiding a reflux of water in case of damage to any coil. The flow and return mains extend along the side walls, pitch upward and have an air relief valve on the ends. The branches to the coils feed downward from these mains.

The garage floor is laid on a 3 in. layer of insulation consisting of crushed tufa, which is a native variety of volcanic rock, and is thoroughly under-drained. Neither the walls nor the roof are insulated and the ends of the building have large windows and garage doors.

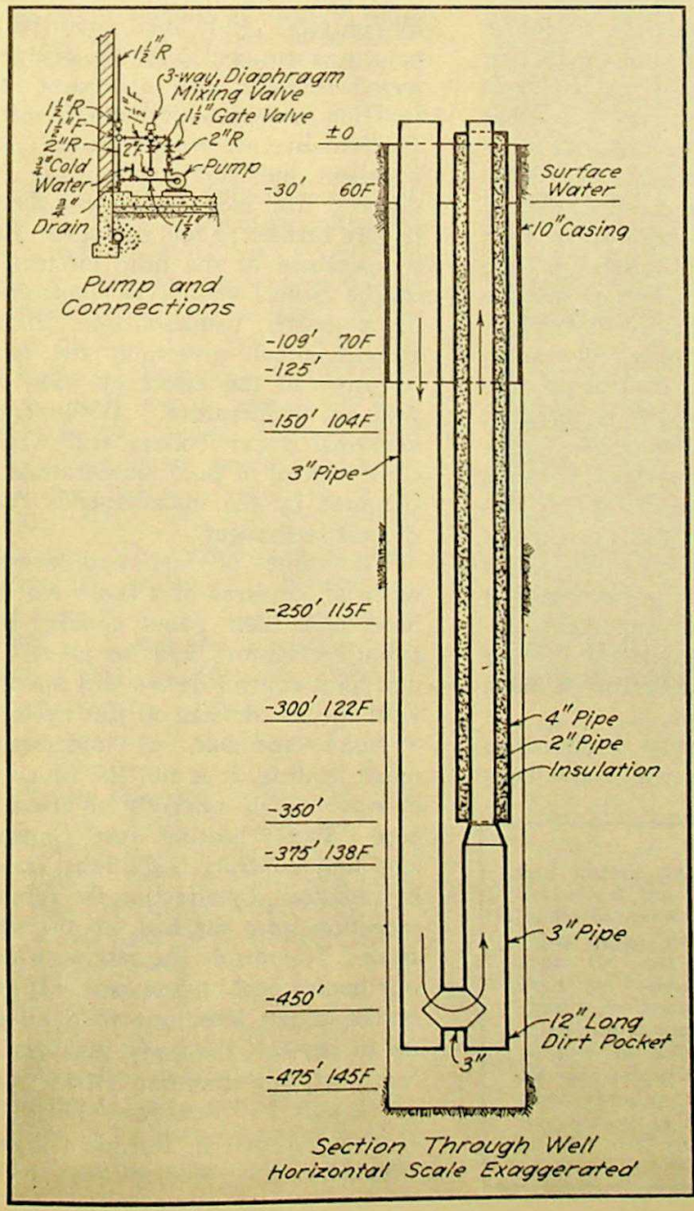
The plant has been in operation since the first of the year and during the coldest weather experienced last winter, plus 15 F, it was found that with only 90 F water the building was warmer than necessary and proved to be very comfortable to the workmen, whose efficiency was not impaired by cold floors.

The building was designed by Howard R. Perrin, architect, and the writer designed the heating system, which was installed by Lorenz Co. It was licensed from Richard Crittall Co., Ltd., through Wolff & Munier, Inc.

Erwin L. Weber, Consulting Engineer, Describes Garage System Which Creates Efficient Work Conditions

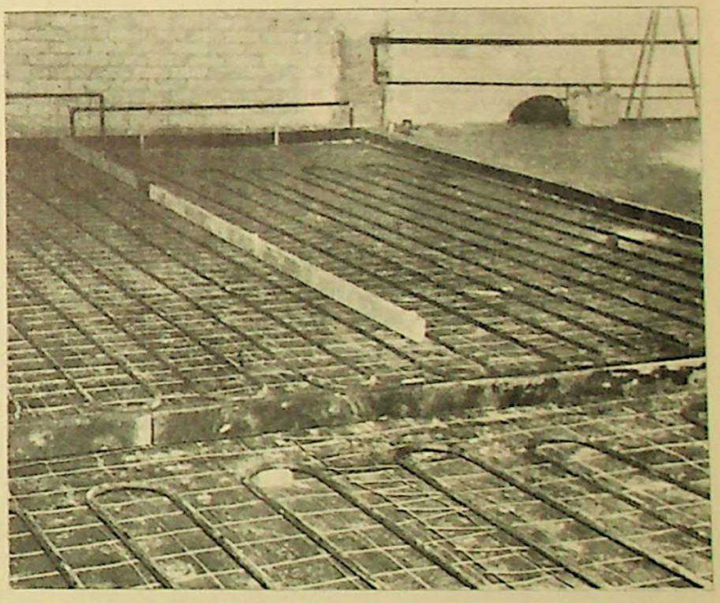


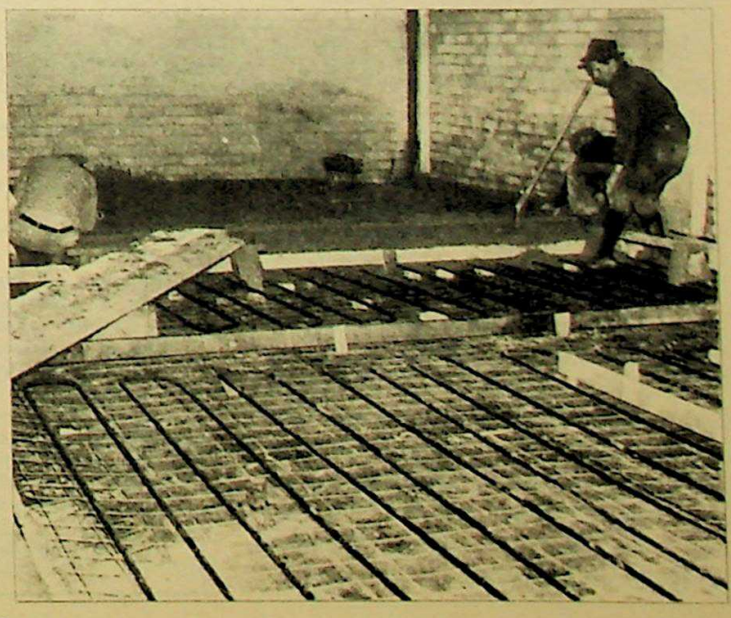
Transverse Section



Pump and Connections

Section Through Well
Horizontal Scale Exaggerated





"Open for Discussion"

Panel Heating

THE EDITOR—

In reality panel heating is a cooling system—yes, a system that controls the rate of cooling of the human body. How can that be possible, you ask? Quite simple, if we but think about it. In grade school we learned that the body when perfectly healthy is at a temperature of 98 degrees. It's kept that way by the food we eat. Every mouthful of food is loaded with energy that is turned into heat. Only a small part of that heat is needed to keep the body alive; the rest must be given up. How? Well, in four ways: By evaporation, convection, conduction, and by radiation. Since the *greater* part of the body heat is surrendered *normally* by *radiation* it is that method with which we must be concerned.

For those interested in panel heating and who do not have a fundamental understanding of the principle of heat exchange by radiation, a brief explanation is in order. We know that heat always moves, flows or travels from the warmer object or surface to the colder one. Heat exchange by radiation does likewise, only it moves in the form of invisible infrared rays through space until the rays impinge on the surface of a wall or object. Heat in this form does not heat the air as the energy moves through it. The air in turn is heated by convection as it wipes either the radiating surface or the surface receiving the radiated energy. This explains why air may be very low in temperature in a room thus heated. If the walls of a room have a high enough surface temperature so that the heat from our bodies does not radiate so rapidly that we feel cold it makes little difference what the air temperature of the room may be. The air will in time assume about the same temperature as the walls unless the air is constantly changed because of ventilating needs and such air is not heated upon being supplied. Since the flow of heat is from the body to the surfaces of the spaces providing comfort it is therefore desirable to control the temperature of those surfaces so the body does not lose heat so fast that it becomes uncomfortable.

Since the control of the room surface temperatures is all important, it is essential to know what those surface temperatures should be as well as how they are to be maintained that way.

The learned Dr. Geisecke has presented formulas for determining surface temperatures for given heat losses and room air temperatures, in his articles in HPAC. He has also established rules for selecting panel temperatures, particularly if only one surface (out of a possible six) is used. It is emphatically pointed out that unless each job is carefully engineered and calculation made according to Dr. Geisecke's method or others equally good that the system just won't give full satisfaction under all conditions.

Perfect engineering can go wrong if poor judgment is exercised in the mechanical application. If the panel used as a radiating surface is constructed in a way that it has a high thermal capacity, then automatic temperature control of the condition in the space is difficult, for the residual heat energy continues to radiate long after controls indicate the desired condition has been secured. This can cause great discomfort, particularly on mild days—to say nothing of wasting fuel. Therefore, an important mechanical requisite seems to be that panels be constructed so as to have low thermal capacity.

Panels that can be fastened to or set in ceilings or walls have been developed. One type has been made by casting small diameter, thin wall copper tubes in a low density, high strength insulating material. The insulation prevents heat flow in the direction where it isn't needed. Being light weight, they are easily handled and require no more support than by screws. The tubes are cast near the surface and so spaced to give the same temperature over the entire panel area. The panels are also given a coat of material high in thermal conductivity in order to improve the radiating surface; this is done, of course, only on the radiating side of the panel. The panels have proved low in cost and high in efficiency.

Of course, no system is better than its controls. Individual room temperatures are controlled by shielded air thermostats set, of course, to function at design air temperatures. Incidentally, air temperatures (experiment indicates) as low as 50 degrees are okay; this can contribute further to fuel savings. The temperature of the fluid circulated in the panels should be controlled by a master inside-outside differential control, preferably the type sensitive to the effect of wind as well as temperature. While conventional water boilers will work, close control of fluid temperature is obtained by the instantaneous type of heat exchanger.

The time is fast approaching when all surfaces of a room will be used and then panel cooling for summer comfort will be here. A dewpoint control device will operate with the thermostat on this cycle.

Just remember, to understand panel heating, it is not the function of warming up anybody or any object. Panel heating just neutralizes and controls body heat losses by radiation, by affecting the rate of radiation from the body to the surfaces. It controls the rate at which our bodies cool or lose heat. If our bodies didn't lose heat we'd all go up in smoke—the body just has to lose heat, but of course not too fast.

—CARL F. BOESTER, Director, Housing Research, Purdue University.

Readers of HEATING, PIPING AND AIR CONDITIONING are invited to contribute their views to these "Open for Discussion" pages, which will appear from time to time. Comments on articles we have published, expressions of timely interest on developments in design, installation, operation or maintenance of heating, piping or air conditioning systems, other remarks of value to HPAC's readers—all will be welcomed by THE EDITOR.

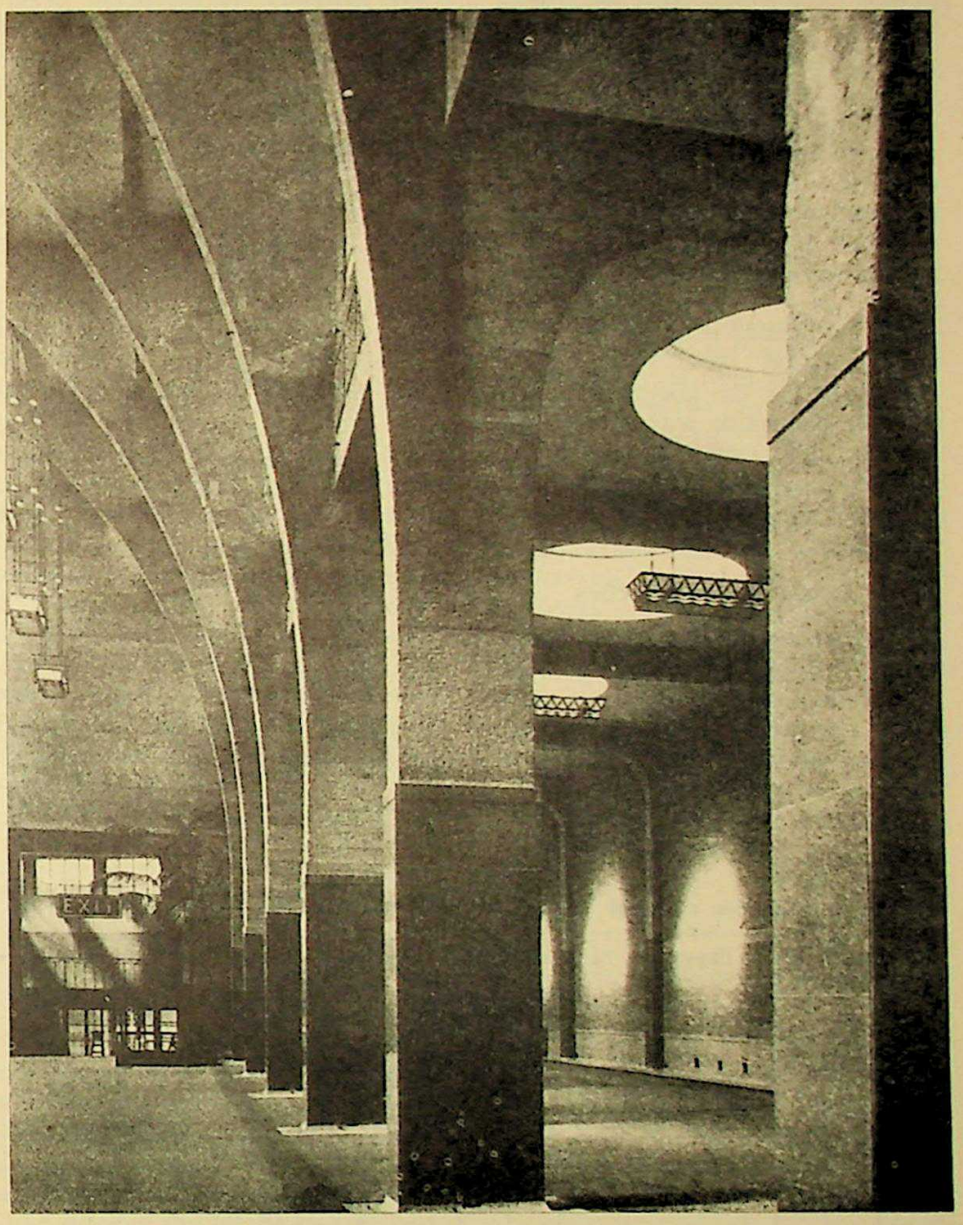
Panel Heating Throughout the World

SUMMARY—So much is heard of panel or radiant heating these days that it seems worthwhile to pause for a look at its use or acceptance throughout the world. We've therefore asked Mr. Hutchinson, instructor in the Department of Mechanical Engineering at the University of California, to analyze the installations in the U. S. and abroad by types of buildings, pointing out the reasons for its applications in the various places where it is used. Mr. Hutchinson was in Europe in 1938 and 1939, where he made a rather extensive study of the subject and of panel cooling. . . . . His article emphasizes the extent and diversity of existing installations. It is pointed out that the uniform temperature gradient with this type of heating is a principal reason for its application to high ceilinged rooms in churches and banks, that an advantage in factories is the possibility of obtaining local regions or zones of comfort in a space where the general temperature level is low, and that in hospitals and schools it provides a means of establishing comfort while still retaining an open air environment. The reasons for the wider acceptance of panel heating in large buildings as compared with residences are also presented

PANEL heating has recently gained considerable attention in the United States, but it is perhaps not yet realized how numerous and diversified are installations of this kind in Europe. The sinuous coil type of panel originated in England and a commonly held belief in the United States is that its development and application have been limited essentially to the British Isles. The list of panel installations which follows is, in itself, substantial evidence to demonstrate the fallacy of the above belief; in addition, it suggests a relative freedom of this system from political, geographic or climatic limitations:

- Headquarters of the Nazi Party, Munich.
- Benito Mussolini Tuberculosis Hospital, Rome.
- Cafe de la Paix, Paris.
- Palace of H. H. Maharajah Gaekwar of Baroda, India.
- Hong Kong and Shanghai Bank, Hong Kong.
- Oslo Town Hall, Oslo.
- City Library, Wiborg, Finland.
- Banque d'Espagne, Madrid.
- Residence, Buenos Aires.
- Bank of England, London.
- British Embassy, Washington, D. C.

Panel heating also travels the seas in three shipboard installations, one of which—on the liner "Queen Mary"—makes use of two different types of panels: the sinuous coil method and the direct electric resistance fabric method.



The 80 ft vaulted ceiling of the Royal Horticultural Hall, Westminster, is heated by means of hot water coils embedded in the concrete ceiling slabs between the arches.

Table 1, based on data supplied by the Invisible Embedded Panel Warming Association, London, shows the extent to which the sinuous coil system has gained worldwide acceptance. Vertically the tabulation permits determination of the distribution of installations among countries, while horizontally it presents a breakdown, for each country, in terms of the type of structure. It will be noted that there are a total of more than 1200 existing installations in 21 countries (Austria and Czechoslovakia are included with Germany; Ireland and Scotland with England).

To a greater extent than is true

Types of Buildings Using It and Reasons for Its Use Analyzed by F. W. Hutchinson, University of California

of other types of heating, the reasons justifying selection of a radiant system vary widely with the type of structure for which the installation is proposed. Readers of HPAC are already familiar with the principal operating characteristics of low temperature radiant heating. These include a low floor to ceiling air temperature gradient, and establishment of equivalent comfort in an atmosphere having an air temperature 5 to 7 F below that which would be needed if convective heating were used.

Considering the above characteristics in connection with some of the structures of Table 1, it should be possible roughly to evaluate the relative advantage of radiant heating for buildings of different types.

Banks and Churches

The first two columns of the table cover banks and churches. Buildings erected for either of these purposes are usually characterized by high ceilings and it would therefore be expected that the choice of radiant heating for such structures would be based essentially on the desirability of reducing the temperature gradient. A numerical example will demonstrate the extent to which this is true.

For a radiator heated room with a 20 ft ceiling the Heating, Ventilating, Air Conditioning Guide of the ASHVE recommends evaluation of the mean temperature in terms of a 2 per cent increase for each foot of height above the breathing level. On this basis the temperature gradient in such a room would be $0.02 \times 20 \times 72 = 28.8$ F and the mean temperature (at the 10 ft level) would equal $72 + (5 \times 0.02 \times 72)$ or 79.2 F. Infiltration air would therefore have to be heated from the outside temperature to 79.2 F and for a mean seasonal outside temperature of 50 F the rise would be 29.2 F. If this same room were panel heated, the mean inside air temperature would be approximately equal to that at the breathing level and the required infiltration air temperature rise would be 22 F. But the temperature at the breathing level with a panel system can be 5 F lower so the actual mean temperature would be 67 F and the infiltration air temperature rise 17 F. Thus the infiltration loss with panel heating would be less than that of a radiator system by $12/29 = 42$ per cent of which $7/29 = 24$ per cent is attributable to the more uniform temperature gradient. (For mean outside temperatures other than 50 F the percentages given would of course vary.)

In addition to the indicated reduction in ventilation load, there would also be an operating saving resulting from decreased transmission losses; the magnitude could easily be determined for a particular case, but is not directly calculable from the air temperatures.

The economy resulting from reducing the temperature gradient is obviously proportional to the height of the ceiling. It becomes most significant in auditoriums or in the entrance halls of public buildings. A striking example of this is the 80 ft vaulted ceiling of the Royal Horticultural Hall, Westminster, which is heated by means of hot water

Number of Panel Warming Installations (Crittall Patents) to 1938—Hot Water Sinuous Pipe Coils Only

Countries	Banks	Churches	Factories	Flats	Hospitals	Hotels	News Bldg.	Offices	Homes	Public Bldg.	Schools	Stores	Ships	Total
England	21	23	10	21	116	22	12	69	133	101	97	81	3	709
France	3	17	7	7	32	18	2	36	83	17	20	10		252
Italy	2	4	2		12			12	14	9	1			56
Germany		2		2	4			10	22	3	4	3		50
Holland	1		1		8	1		5	4	1	1	7		29
Switzerland			2	1	10			2	10	1		1		27
Sweden				7	2	1		2	2	6	3			23
Denmark	4		1	3	2	2			2		9			23
Belgium		1		1				1	8	1		2		14
Spain	1				1			1	2	4				9
Bulgaria				1					5					6
Norway					1			1		3		1		6
Algeria					3				1					4
U. S. A.					1				1	2				4
Finland				1						2				3
India									1	1	1			3
Argentina			1						2					3
Hungary									1					1
Uruguay					1									1
China	1													1
Egypt								1						1
Total	33	47	24	44	193	44	14	140	291	151	136	105	3	1,225

coils embedded in the concrete ceiling slabs between arches.

Factories

The importance of reduced temperature gradient would not be so great in the case of factories (third column of Table 1), but here too it is frequently a factor. A more important advantage of radiant heating for warehouse, factory or other large open structure installations is that it enables establishment of local regions or zones of comfort in a room for which the general temperature level is low. This characteristic of panel systems is important whenever the density of occupancy is low or non-uniform. In this respect the use of panels is somewhat analogous to the use of luminaires to increase the intensity of illumination in parts of an office for which the general level of illumination is insufficient.

Hospitals and Schools

With hospitals and schools, an important advantage is the possible reduction in ventilation heating load. High ventilation rates are commonly used in such structures and hence a marked economy would be expected from a 5 to 7 F reduction in air temperature. More important, however, is the fact that panel heating provides an effective means of establishing comfort while retaining the advantage of an open air environment. In some hospitals, panel heated wards are completely open to the atmosphere on one or more sides. Authorities at the Winford Orthopaedic Hospital in London state that their patients are comfortable in such wards even when the inside air temperature is as low as 53 F (with an outside temperature below freezing).

Stores and Offices

For stores, offices and public buildings an advantage frequently claimed is that the lower inside air temperature reduces the shock accompanying short time occupancy of any heated or cooled space. A health point sometimes raised in this connection is that the relative humidity in a panel heated structure does not drop as low as in buildings heated by other systems.

Residences

Table 1 shows that of 1225 panel heated structures 291 are residences. This fact is of particular interest. It suggests a much more rapid acceptance of the panel system for large in contrast with small structures. Since the number of residences exceeds by many times the number of buildings of all other types, it is perhaps significant that there is only one residential installation for three in larger buildings. It is not within the scope of this article to attempt an evaluation of the factors responsible for the above circumstances, but the more important of the causes which are thought to contribute are listed below:

1) Central heating is not commonly used in European and English homes. While the potential field of application to residences is much greater than that to other kinds of buildings, the actual market for heating is largely in business or public structures.

2) The relative cost of a panel installation is greater for small than for large buildings because:

a) Heat losses from the rear of the panel are greater. In multi-story buildings the entire heat input to all ceiling panels except those in the top story goes to the structure; in single story buildings the loss through the roof is obviously much greater. This disadvantage can be offset by insulation, but only at greater capital cost.

b) First and operating costs of a panel system are least when it is operated continuously. For small structures intermittent operation of the heating plant is preferable, but with panels this would necessitate the provision of considerable additional surface for start up and would introduce control problems due to the greater thermal capacity of such a system.

Summarizing, it may be said that panel heating is especially suitable for buildings with high ceilings and high rates of ventilation. As these two factors are reduced the value of lower temperature gradient diminishes until, for a low ceilinged store or residence, it is of no significance. The value of the 5 F or more reduction in mean air temperature is, of course, valid for any type of building.

Panel Heating in U. S.

One more item in connection with Table 1: The position of the United States, between Algeria and Finland, is noteworthy. Why has the acceptance of panel heating been so much slower in the U. S. than in other countries? Evaluation of the reason is difficult, but some contributing factors are listed below

1) Central heating was commonplace throughout the United States before the development of the panel system. In consequence,

a) There was not the same incentive to the development of a new system.

b) Competition with other methods would have been much greater than in Europe where central heating in any form was largely unknown.

2) People in this country were used to the equipments of convective heating and do not object, as do the English, to the presence of visible heating elements.

3) Central heating has for so long been an essentially American development that it requires some effort to recognize a change in method which originated in a country long recognized for the inadequacy of its heating methods.

4) Since the panel system is designed for continuous operation it is well adapted to the use of offpeak electrical energy. This fact has contributed to the popularity of the panel system in England since unusually low rates have been available there to users of large blocks of offpeak energy.

In conclusion, attention is again called to the fact that Table 1 covers sinuous coil embedded panel installations *to* 1938 only.

Other methods of panel heating are widely used throughout Europe. Among these are the cast iron plate type and the electric fabric type. The total number of complete panel installations is in excess of 2000 and it has been estimated that an equal number of individual detachable panels are in service.

RADIANT HEATING
—With Cast Iron Panels

F. W. Hutchinson, of the University of California, Describes and Discusses a Method Used in Europe

THE principle of heating or cooling by means of low temperature radiant energy consists essentially in establishing a designed fraction of the total internal surface of the room at a temperature determinable from the heat transfer characteristics of the structure and the comfort requirements of the occupants. The effectiveness of such a system is then a function only of the area and temperature of the panel surface, which acts in winter as a heat source and in summer as a heat sink. Obviously, therefore, selection of a particular type of panel is not dictated by radiant comfort theory, but follows from considerations such as relative responsiveness to control, flexibility of operation, and ability of the panel to provide the requisite energy transfer from the circulating fluid to the working surface. Other factors influencing the selection are maintenance and repair experience, structural requirements, architectural desirability and first cost.

The intent here is to describe and discuss a widely used European method of panel construction which has received but scant attention in the United States. This method, using cast iron plates, differs strikingly from the sinuous embedded coil and electric fabric systems of which adequate descriptions have already appeared. Basic differences are:

1) The cast iron panel is manufactured complete in standard sections ready for assembly and installation by the heating contractor.

2) The panel surface receives heat transferred from cast iron waterways and is itself either an integral part of the waterway casting or a steel plate affixed to that casting.

3) Units are attached to or recessed into the ceiling or wall, but do not become an integral part of the structure. For this reason they are sometimes referred to as "applied" in contrast to "embedded" panels. Architecturally the unit is therefore at a disadvantage when compared with the sinuous coil or electric fabric methods since it is not invisible.

If a cast iron panel system were operated at the surface temperature used with embedded panels the comfort characteristics, energy require-

SUMMARY—A method of panel construction for radiant heating used widely in Europe but which has received scant attention in the United States is described and discussed by Mr. Hutchinson, instructor in the department of mechanical engineering at the University of California. He writes from a first hand knowledge, for he has spent two summers abroad making studies of radiant heating and cooling. . . . The method utilizes cast iron plates manufactured in standard sections ready for assembly and installation by the heating contractor. The units are attached to the ceiling or wall but do not become an integral part of the structure; for this reason they are sometimes referred to as "applied" rather than "embedded" panels. . . . The various types of these panels are described and analyzed. The author concludes by pointing out that such panels are not intended to be competitive with low temperature (90-100 F) ceiling panels, but when used in the temperature range for which they have been developed, they provide a means of realizing some of the characteristics of radiant heating

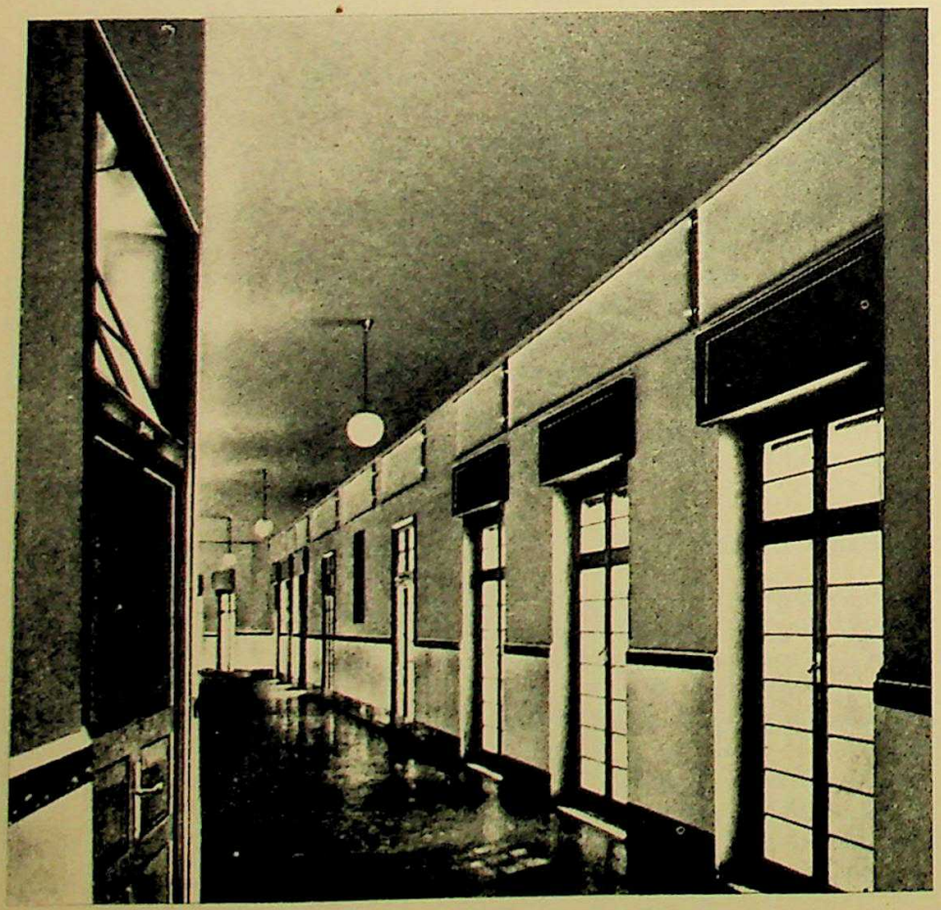


Fig. 1—Installation of all cast iron panels comprising a casting flat on one side and with integral water passages on the other

ments and equilibrium performance of the two systems would be similar. In practice, the panel manufacturer recommends its use at temperatures higher than those common with sinuous coils; in consequence, a direct comparison of performance is not possible. Differences occur in a number of respects.

in terms of its shape factor with respect to the occupants is of greater importance with this type than with low temperature (90-100 F) panels. The manufacturer takes this into account by recommending arbitrary reductions in rated heating effect for installations which differ from a stated design standard.

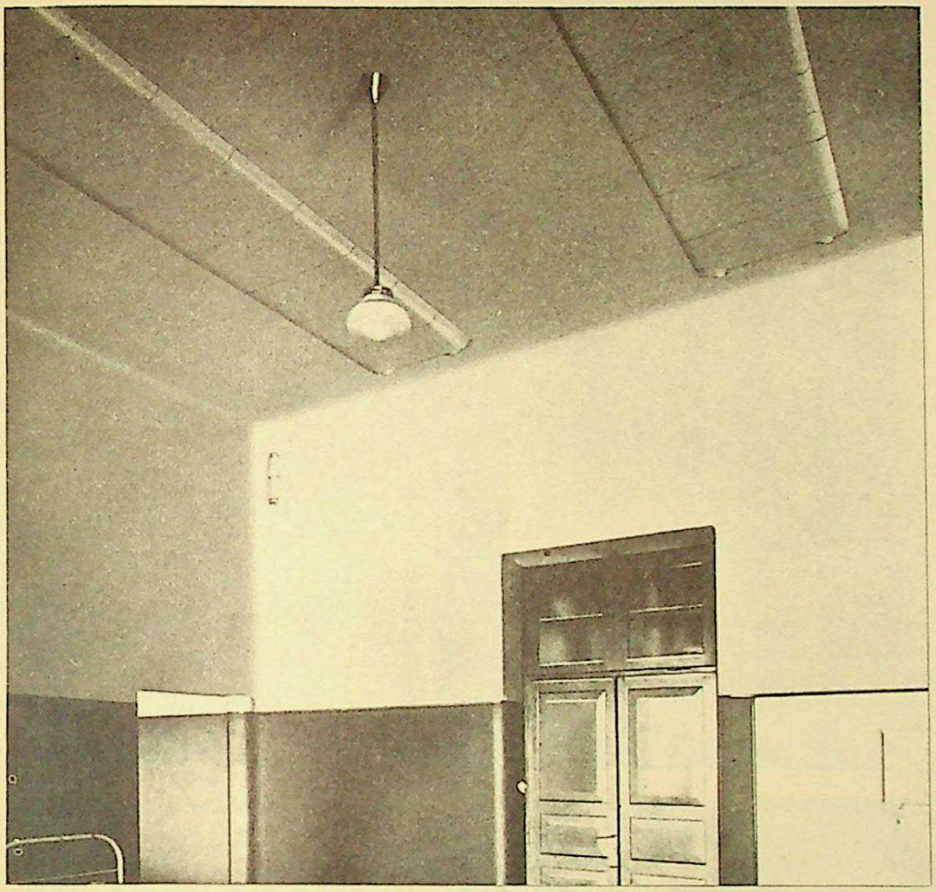


Fig. 2—Another view of hospital shown in Fig. 1. The panels are on the ceiling

High Temperature

Hot water above 160 F or steam is customarily used as the heating medium. The higher surface temperature consequently increases the panel rating and reduces by approximately one-half the necessary panel area. While such a reduction is desirable in terms of first cost it tends to obviate one of the principal advantages claimed for panel warming: uniformity of heating effect. In this respect the need for a careful analysis of panel position

Another result of the higher flow temperature is a more rapid cooling rate and consequently an improved response to changes in the outside temperature. Responsiveness is further assisted by the lower thermal capacity of these panels—a characteristic which is also of value in that it reduces the requisite heating up period. This latter effect, however, is not a serious disadvantage of other types of panels since such systems are intended for continuous operation during the heating season.

Capacity

The cast iron panels are regularly used for floor and wall as well as for ceiling installations. Calculations based on the published ratings show that the percentage of the total heat dissipation which occurs by radiation is 53, 56 and 75 per cent for floor, wall and ceiling respectively. On this basis the convective heat transfer increases by

$$\left[\left(\frac{100-53}{53}\right) \div \left(\frac{100-75}{75}\right)\right] 100 = 265 \text{ per cent}$$

when a panel is moved from the ceiling to the floor; it follows that floor installations (and wall also, though to a lesser degree) represent a compromise between radiant and convective heating and the characteristics of such systems must be somewhere between those of low temperature radiant ceiling panels and of warm air heating installations. Such advantages as accrue

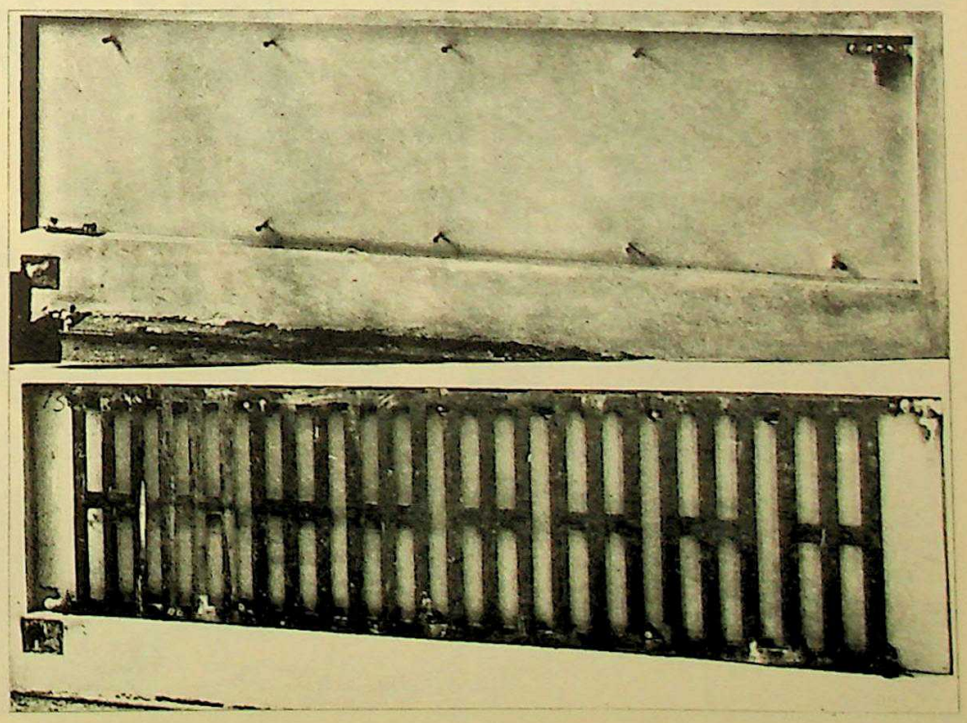


Fig. 3a (above)—Wall recess prepared for installation of panel comprising independent cast iron waterway section to which is attached a flat steel sheet. . . . Fig. 3b (below)—Waterway in position and ready for the plate. Insulation board has been placed behind the waterway

from radiant heating are therefore realized to a lesser extent as the panels are moved down from the ceiling. (Note that for radiant cooling the opposite is true.)

Method of Sizing

Determination of the necessary panel area for a given installation is based on heat losses calculated exactly as for a convective system, but used with equivalent panel ratings which are an index of the relative heating effect. For floor, wall and ceiling panels the heating effects are said to be 25, 33 and 50 per cent, respectively, greater than the actual heat dissipation rates. Thus the requisite area of ceiling panel would be determined by dividing the standard room heat loss by 1½ times the actual rating of the panel. *On this basis* the fuel requirements of a cast iron panel heated structure would be less than for convective heating by 20, 25 or 33 per cent, depending upon whether the panels were situated in floor, wall or ceiling.

Construction

These cast iron panels are factory made in standard sections of four types. The requisite heating surface for a given installation is obtained by connecting in series, by means of right-left internal nipples, the necessary number of sections.

One type is a 100 per cent cast iron unit made in sections 16 in. wide by 18, 24 or 30 in. high. The casting is flat on one side with integral water passages on the other. Heat flows from the fluid passages through the plate by conduction; spacing of the waterways is designed to effect a relatively uniform temperature across the front surface. A flanged bead is cast at the back of the plate and the unit is adapted for flush, recessed or projected fixing. This type has an actual heat dissipation rate of 170 Btu per sq ft per hr when installed in the ceiling, operated with a water to air temperature difference of 100 F and insulated with 2 in. of rock wool. Figs. 1 and 2 show typical installations in an Italian hospital.

Another type differs radically from the foregoing. It consists of an independent cast iron waterway section to which is attached a flat 14 ga sheet steel plate. The unit is lighter and less costly than the all cast panel and is somewhat more adaptable since it is possible to affix a plate of any desired shape and size. It is designed for flush installation in either wall or ceiling.

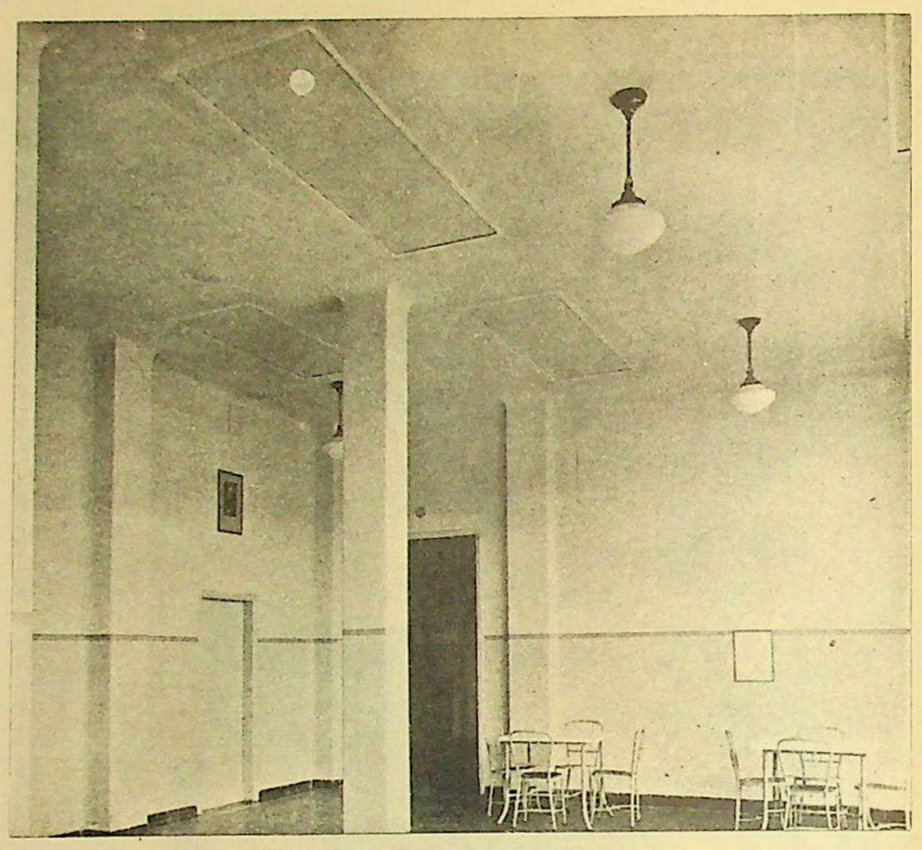


Fig. 5—A completed ceiling installation. The molding around each hot plate insures an air tight connection to prevent streaking the unheated ceiling with dust

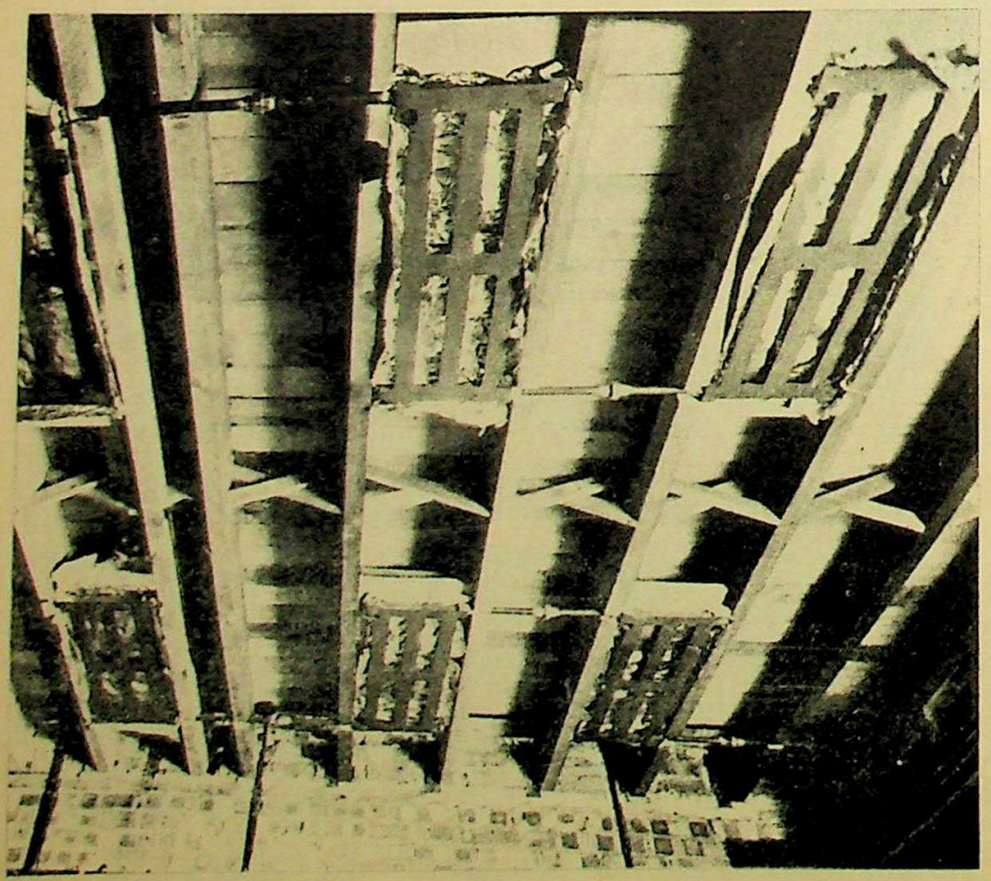


Fig. 4—Same type of panels as shown in Fig. 3 used in a ceiling and foil insulated

Fig. 3a shows a wall recess prepared for this type. Studs are embedded in the wall at regular intervals and on these the cast waterways will be hung. Hot water or steam will enter through the valve shown in the upper right hand corner of the recess and after passing diagonally through the heating

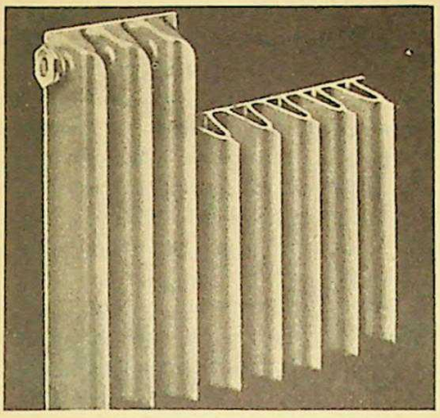


Fig. 6—This type of panel has an extended surface on the back over which air passes to be heated by convection. This unit really resembles a convector more than it resembles a radiant panel

elements will exit through the discharge pipe shown in the lower left.

Fig. 3b shows the waterway in place. Note that the heating unit consists of eight sections connected by internal nipples. In this figure it will be observed that a sheet of ½ in. insulating board has been placed behind the waterway; the unit is now ready to receive the flat radiating surface. The plate will be affixed with screws and pulled tight against the bearing surface to reduce the resistance to heat flow.

Fig. 4 shows the same type of sections used in a ceiling and insulated with foil.

Fig. 5 shows a completed ceiling installation. A molding is visible around each hot plate; this is needed to insure an air tight connection between the plate and the surrounding unheated ceiling since, if there were leakage, dust streaks would appear on the unheated part of the ceiling radiating out from the hot panels.

A third type is similar to that just described, except that the metal plate has curved edges to permit fixing to wall or ceiling where flush installation is not possible. This type is particularly well adapted to use in revising the heating system of an existing structure. The plate edges are provided with a recess which is fitted with an asbestos packing material.

A fourth type, like the first described, is 100 per cent cast iron, but is constructed with an extended surface at the back of the plate and is usually installed so that air passes over the unexposed side of the plate and is thereby heated by convection. Eight vertical extended waterways are cast in every section and the resistance to heat flow is so small that the flat surface approaches a uniform temperature which is but slightly below the temperature of the heating fluid. A cross section through such a unit is shown in Fig. 6. This type is less expensive to install than others because the additional surface increases its actual heat dissipation rate to more than 3½ times that of a ceiling installed unit of like area and operating at the same surface temperature. However, the added capacity is all in convection and the actual radiant fraction of the total energy from such a unit is so small (below 20 per cent) that it might with some justice be said to resemble a convector more closely than a radiant panel. Its principal advantage is that the flat exposed surface lends itself to incorporation into the decorative scheme. Fig. 7 shows a typical wall application.

Application

Statistics are not available as to the number of existing installations using these panels, but there are more than 100 in Italy alone and many times that number in England. A conservative estimate of total European installations would be 500.

In conclusion, it is to be emphasized that panels of this type are not competitive with sinuous coil or electric fabric in the field of low temperature (90-100 F) ceiling panels. The first cost of the cast iron panels for such service would be in excess of $1.50 per 100 Btu per hr and (for panels exclusive of piping and boiler plant) would be prohibitive. But it is meaningless to even make such a comparison since the cast iron panel was never designed for operation under these conditions. When used in the temperature range for which they were designed, these panels provide a practical method of realizing some of the characteristics of radiant heating.

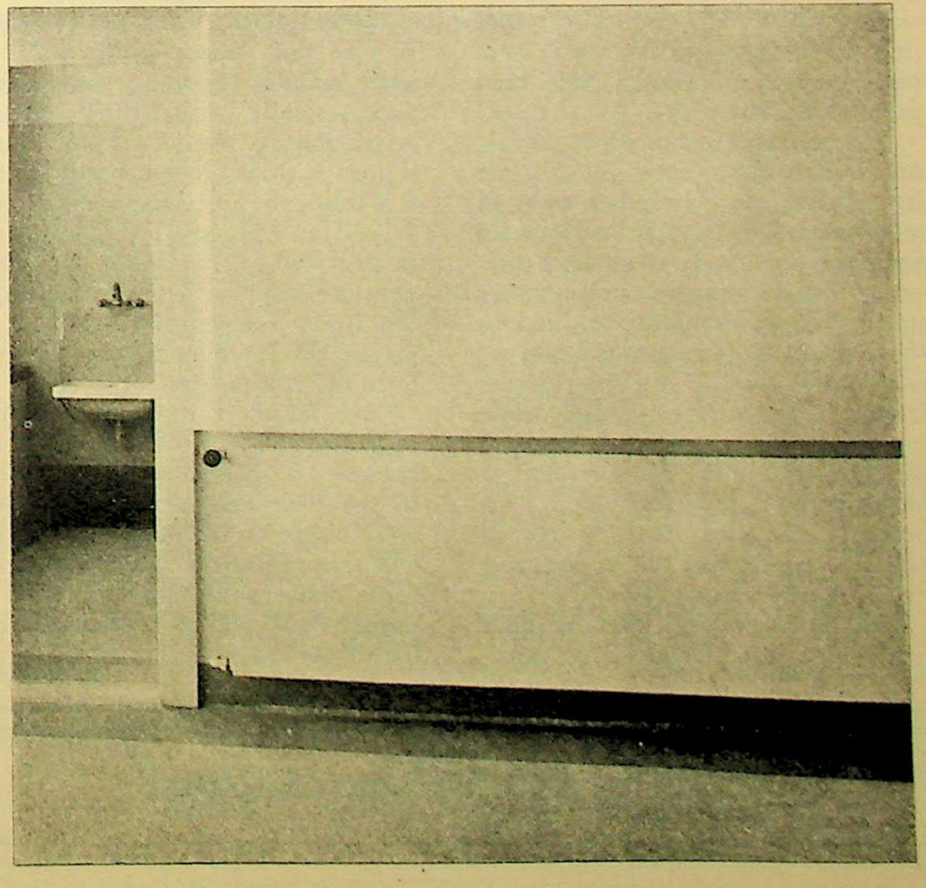


Fig. 7—Typical wall application of the unit illustrated in Fig. 6, showing how it fits into the general decorative scheme

RADIANT HEATING WITH CAST IRON PANELS

THE EDITOR—

Since I have been associated with these cast iron panels for radiant heating from the time they were first designed by my friend A. H. Barker over 20 years ago, and since I have designed many other different types of metal panels used in connection with radiant heat installations, I was particularly interested in the article by F. W. Hutchinson in the April HPAC. Mr. Barker, after disposing of the patent rights for the embedded pipe method of panel heating, designed and patented the cast iron panels to provide a flexible method of radiant heat and a unit which could be applied to existing buildings without extensive structural alterations.

I think the first cast iron panels installed in America were erected in the library of the Pennsylvania College for Women, Pittsburgh, in 1932. These I ordered direct from England as they could not then be obtained in this country. They were installed to overcome complaints of drafts. The librarian found it impossible to keep warm and was continually catching colds, although the air temperature was always 72 F or above. After the panels were installed all complaints ceased, and during the eight years these have been in use, the results have been perfectly satisfactory.

Mr. Hutchinson implied in his article that the adoption of the cast iron panels or any other type of metal panel is not in accordance with the radiant heat comfort theory. This statement is somewhat misleading, it seems to me, because the whole theory of radiant heating is to take care of the heat losses from the human body; and while low temperature radiation appears to provide better comfort and a healthier condition than high temperature radiation, there is not as yet any very definite line of demarcation of surface temperatures.

The metal panels—whether made from cast iron sections, or fabricated from sheet steel plates to which are welded wrought iron pipes to form steam or waterways—are cheap to provide, easy to install and flexible in operation. Moreover, they do not present any great obstacle when changes in the internal construction of a building are necessary.

I installed a number of metal radiant heat panels in our work offices at Bethlehem, Pa., over five years ago, with perfect results. These panels are fabricated with steel plates which fit into some of the lower panels of the wood partitions. Coils of ¾ in. wrought iron pipe are spot welded to the steel plates and these are connected to the steam heating system in the usual manner. A radiant heat room thermostat controls the supply of steam according to the mean radiant temperature and the air temperature.

Radiant Heat for Powder Plants

At the present time I am designing a radiant heat system for several large powder plants for which sheet metal panels are contemplated. They are to be connected to one central steam supply.

The panels recommended are to be placed on the walls and will not occupy floor space which will be very valuable for the process work and, secondly, with radiant heat it is possible to provide comfort conditions with an air temperature 6 to 8 F below the air temperature necessary if an ordinary heating system is provided. This lower air temperature, coupled with the fact that the lower temperature means a higher relative humidity, should reduce the risk of fire.

The reason I recommended the radiant panels for the side wall was because, if the panels were placed in the floor and boxes of powder were placed on the floor, heat might generate below the boxes sufficient to be dangerous. The surface of a heated floor will soon become very hot if the radiation is stopped, as would be the case with boxes resting on the surface. I ruled out the question of radiant panels in the ceiling because these buildings are invariably constructed with a very light roof, which will be easily lifted in the case of an explosion. In the particular case in question, the roof will be high and not by any means airtight.

Mr. Hutchinson mentioned in his article that metal panels are regularly used for floor and wall as well as ceiling, but I have never seen these used for the floor except in systems known as "border" heating. The metal panels are then made narrow and used only in such places as aisles of churches or adjacent to walls and other places not usually occupied for standing or sitting. If the surface temperature is above 160 F, as Mr. Hutchinson mentions, it would be impossible to tolerate such high temperatures for the feet.

Radiant Heating Calculations

Concerning the question of calculations for radiant heating, it admittedly was customary in the early days of radiant heating to calculate the surface on the basis of heat transmission losses as in the case with convectional heating systems; but for many years heating engineers have based their calculations on the mean radiant temperature or MRT of the room compatible with the heat losses from the human body.

I have maintained for years that only when we realize that true comfort and health can only be maintained by taking care of the actual heat losses from the human body in a way that will meet the correct physiological and psychological reactions of the person shall we be on the right road to design correct heating and air conditioning systems.

It may be correct to say that in making calculations on the basis of heat losses through walls, etc., a close approximation may in some cases result; but on the other hand, it is a very dangerous procedure, because many disappointments will follow and the reputation of radiant heat will suffer. Those who have had no actual experience with radiant heat will be well advised to go carefully and if not sure should err on the right side, for once a radiant heat system is installed, it is a very

"Open for Discussion"

expensive job to make additions or changes.

Capacity

Under the heading of "Capacity" Mr. Hutchinson remarked that "floor installations represent a compromise between radiant and convective heating." This is an argument of those using embedded pipes in the ceiling, but it is not substantiated by facts. The theory of radiant heat is to take care of the individual heat losses from the human body and the question as to whether the radiant panels are in the ceiling, floor or walls must be decided according to the type of building and the use to which the rooms are put.

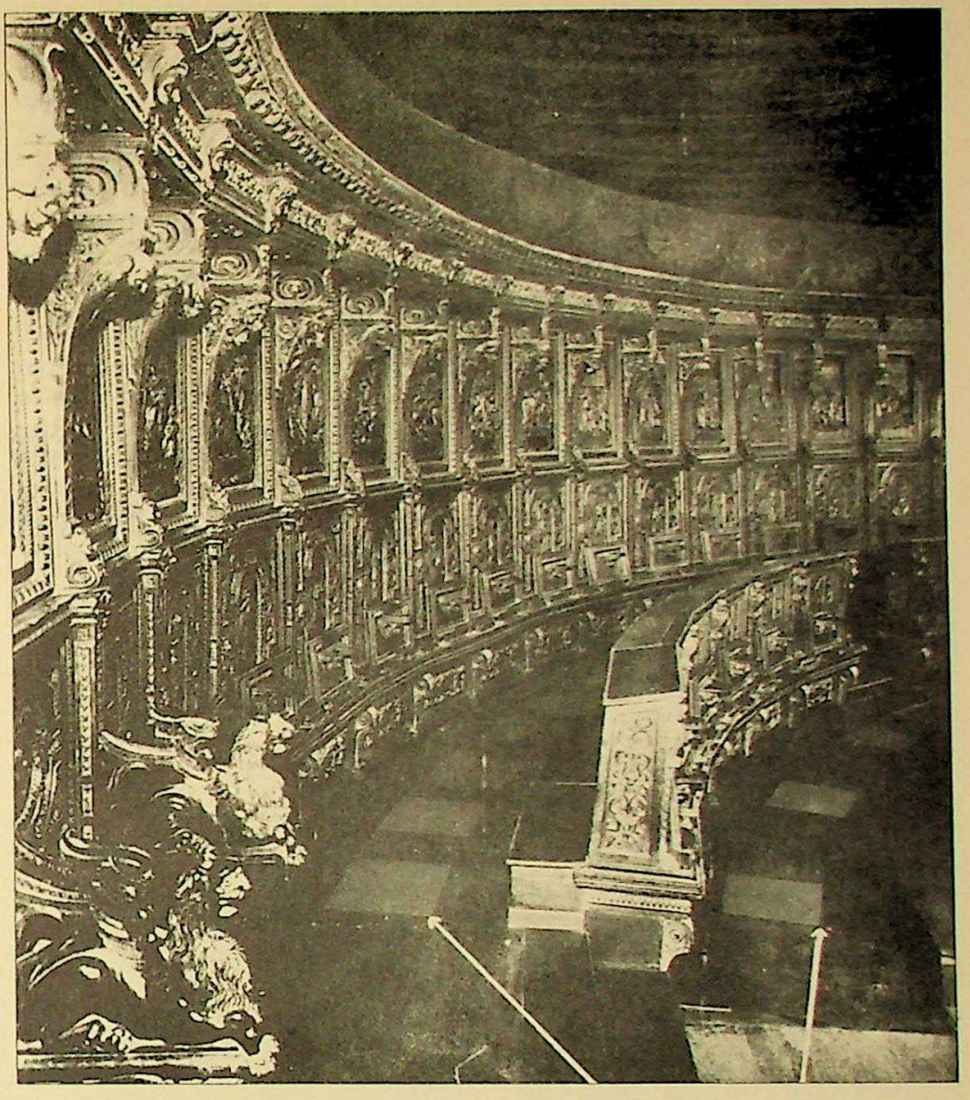
The statement "Such advantages as accrue from radiant heating are therefore realized to a lesser extent as the panels are moved down from the ceiling", overlooks the fact that the floor surface must be much cooler than is permissible for either the walls or ceiling. It is true that a heated surface on the floor will give off more heat by convection than a similar surface on the ceiling, but this is more than counteracted by the lower floor temperature. This is substantiated by the results of my test taken at the Liverpool cathedral (as described in HPAC in July, 1938) where the air at high level was cooler than at low level.

In reference to the special panel in Fig. 6 of Mr. Hutchinson's article, it may be of interest for some to know that this type was originally designed several years ago for the large Shell Mex building overlooking the Thames in London. As additional heat was necessary to provide extra ventilation, this type of panel was introduced for the purpose of obtaining more convected heat for ventilation without raising the mean radiant temperature too high.
—T. Napier Adlam, chief engineer, Sarco Co., Inc.

Reply by Mr. Hutchinson

The Editor—

Mr. Adlam states that my article "implied that the adoption of the cast iron panels or any other type of metal panel is not in accordance with the radiant heat comfort theory." In the opening paragraph of my article it was stated that the "selection of a particular type of panel is not dictated by radiant comfort theory . . .," while in the third paragraph appeared the statement, "If a cast iron system were operated at the surface temperature used with embedded panels the comfort characteristics, energy requirements and equilibrium performance of the two systems would be similar".



Floor installation at Milan cathedral

Commenting on the above "implication", Mr. Adlam discusses the comfort and health effects of high and low temperature radiation and states that there is not a definite "line of demarcation of surface temperatures". At no point in my article was the difference in comfort or health effects due to irradiation with energy from low or high temperature sources used as an argument either for or against the cast iron system.

In Mr. Adlam's comment there appears the statement that "if the surface temperature is above 160 F, as Mr. Hutchinson mentions . . ." My article did not state that the *surface* temperature is above 160 F.

As to the method of calculation and the data on heating effects given in my article, this information was obtained at the head office of a manufacturer of the cast iron panels; much of this information is available in engineering bulletins published in England and Italy by the manufacturers.

Mr. Adlam correctly states that "for many years heating engineers have based their calculations on the MRT of the room. . . ." This is the basis of the method described

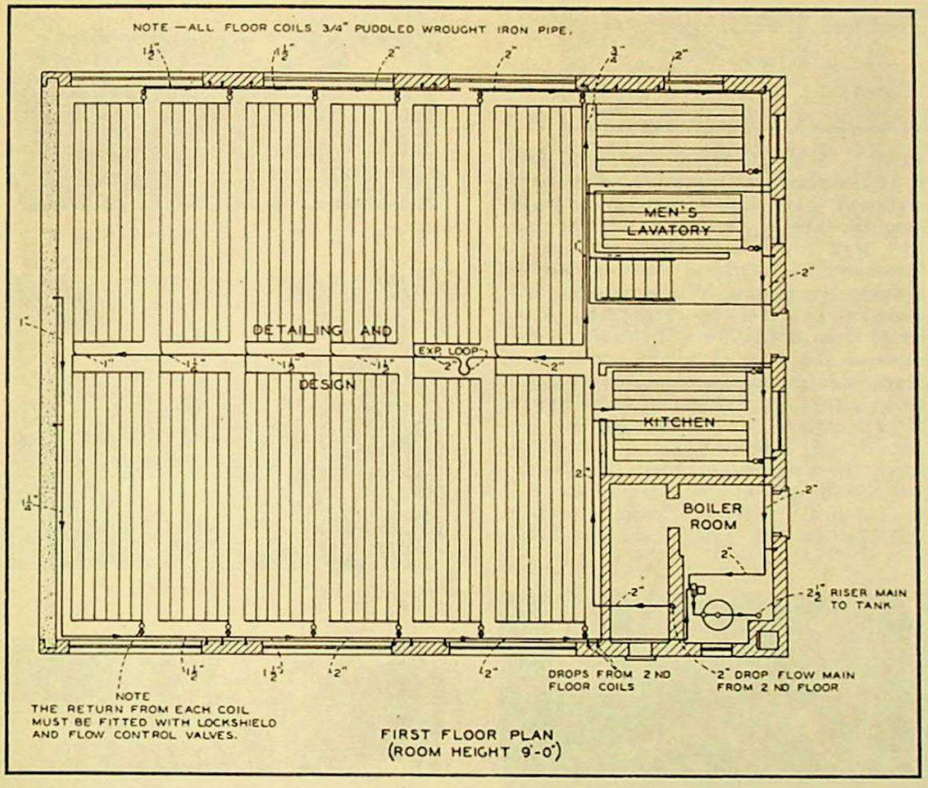
"Open for Discussion"

in my article and recommended by the two largest European manufacturers of cast iron panels. Transmission losses influence the inside equilibrium surface temperature and are therefore a factor in calculation of the MRT; the method here used involves the use of experimentally determined "equivalent panel ratings" which are non-rational coefficients that take into account the reduction of air temperature which is permissible with a higher MRT. This is brought out by the manufacturer's statement that if room air temperatures must be guaranteed the designer should use the actual heat dissipation rate of the panel rather than the "equivalent heating effect". The method described in my article is the one used in the great majority of English and continental cast iron panel installations.

The statement that wall or floor panels are less effective than ceiling panels for radiant heating is said by Mr. Adlam to be not substantiated by facts and an argument of those using embedded pipes in the ceiling. The most significant advantage claimed for radiant heating is that it permits realizing comfort in a room with reduced air temperature. Application of the heat transfer and heat balance equations from any text will provide unquestionable substantiation for the fact that the magnitude of the inside air temperature reduction decreases as the fraction of heat transfer by convection increases. Application of the same equations will also demonstrate that the advantage claimed for ceiling installation does not "overlook the fact that the floor surface must be much cooler than is permissible for either the walls or ceiling"; for the same MRT a lower temperature necessitates a larger area and the energy input to the low temperature floor system will exceed that to the warmer ceiling system. Practical substantiation for the claim of greater effectiveness of ceiling installations is available from the published ratings of cast iron panels. Reference to one manufacturer's catalog will show that the heating effect per Btu of actual energy input increases as the panel is moved from floor to wall to ceiling; obviously, therefore, it is the contention of the manufacturer that the effectiveness of the system, as measured by fuel consumption, will be greatest with a ceiling installation.—F. W. HUTCHINSON, instructor, department of mechanical engineering, University of California.

RADIANT HEATING JOB PICTURED

By T. NAPIER ADLAM*

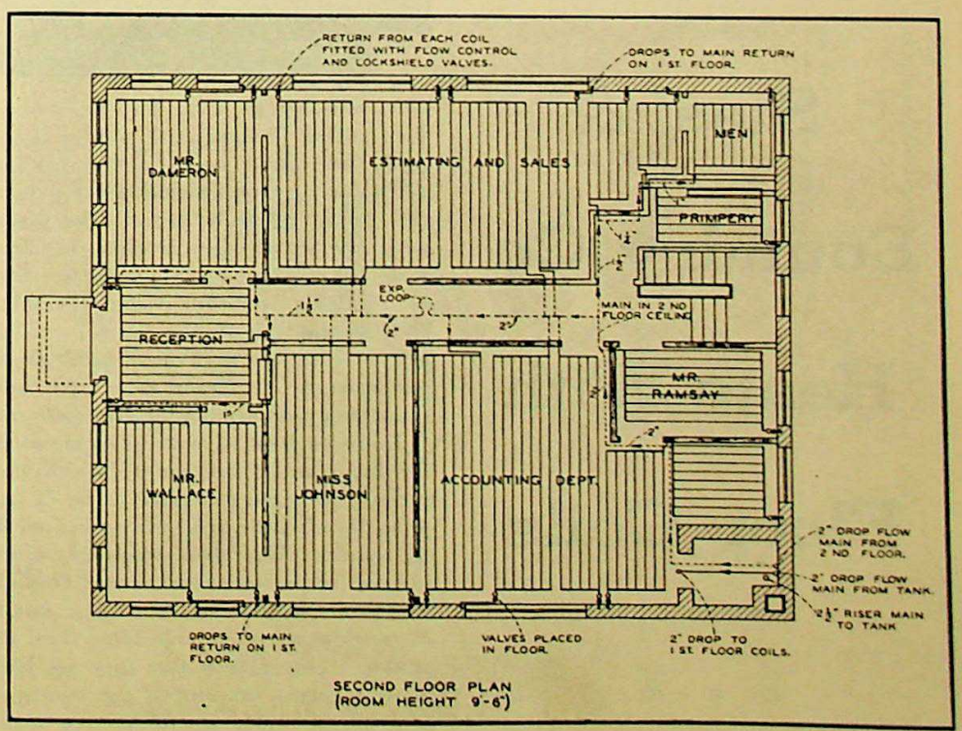

NOTE — ALL FLOOR COILS 3/4" PUDDLED WROUGHT IRON PIPE.
MEN'S LAVATORY
DETAILING AND DESIGN
EXP. LOOP
KITCHEN
BOILER ROOM
2½" RISER MAIN TO TANK
DROPS FROM 2 ND FLOOR COILS
2" DROP FLOW MAIN FROM 2 ND FLOOR
NOTE
THE RETURN FROM EACH COIL MUST BE FITTED WITH LOCKSHIELD AND FLOW CONTROL VALVES.

FIRST FLOOR PLAN
(ROOM HEIGHT 9'-0")

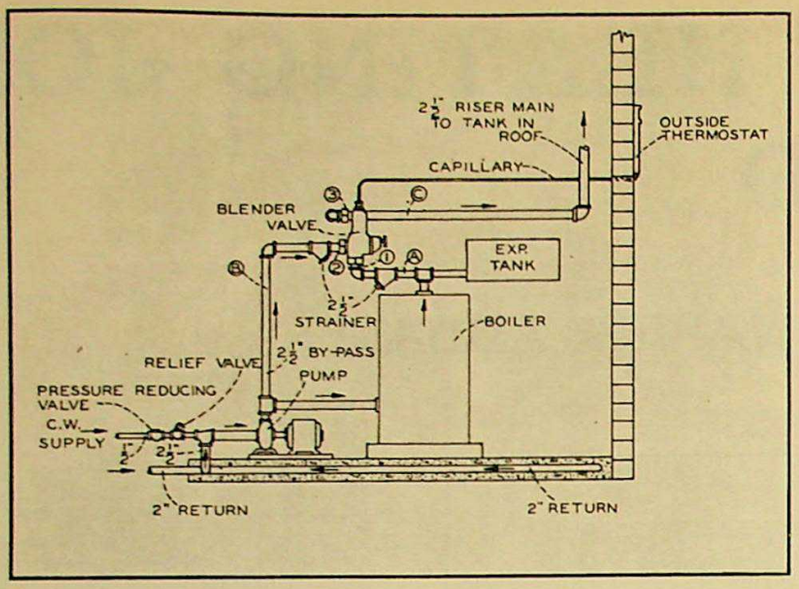
WHEN RADIANT heating comes up for discussion, the installation in the new offices of the Greenville Steel & Foundry Co., Greenville, South Carolina, is usually mentioned. A complete radiant job with pipes embedded in the floors, it was in operation all last winter with satisfactory results. Although complete data aren't available, worthwhile economies in fuel oil consumption over more conventional heating systems are indicated; installation costs compared favorably with other types of heating. . . . The system was designed to give the greatest comfort effect without raising the floor temperature beyond that compatible with the physiological reactions of the most sensitive persons. A letter from the owner shows that the objectives of the design have been achieved. Despite the fact that 20 deg weather was experienced on several occasions, no hot spots in the floor could be detected, and the floor felt cool to the touch although it heated the building. One day, someone opened a wrong valve and 180 deg water was forced through the pipe coils for several hours that night. Even the excessively high temperature caused no apparent cracking of the concrete floor. . . . It is planned to circulate cold water through the floor coils in summer to give a cooling effect

*Chief engineer, Sarco Co., Inc.

The layout of the pipe coils in floor for the first story, and the layout of the pipe coils which are embedded in the floor of the second story, are shown here. The building is a two story structure, about 40 by 50 ft, and is constructed with 12 in. brick walls, the insides of which are painted. The windows are made with steel sashes and single glazing. The ground floor has a 2 in. concrete slab covering on top of 8 in. broken stone fill. The ceiling construction of both floors consists of bar joists, approximately 12 in. deep. The floor of the second story and the roof above it have a 2 in. concrete slab. On the top of the 2 in. concrete slab of the roof a tar and gravel covering forms a composition roof. Insulation is used in the ceiling in order to minimize the transmission of heat


RETURN FROM EACH COIL FITTED WITH FLOW CONTROL AND LOCKSHIELD VALVES.
DROPS TO MAIN RETURN ON 1 ST FLOOR.
MR. DAMERON
ESTIMATING AND SALES
MEN
PRIMPERY
EXP. LOOP
MAIN IN 2 ND FLOOR CEILING
RECEPTION
MR. RAMSAY
MR. WALLACE
MISS JOHNSON
ACCOUNTING DEPT.
2" DROP FLOW MAIN FROM 2 ND FLOOR.
2" DROP FLOW MAIN FROM TANK.
2½" RISER MAIN TO TANK
DROPS TO MAIN RETURN ON 1 ST FLOOR.
VALVES PLACED IN FLOOR.
2" DROP TO 1 ST FLOOR COILS.

SECOND FLOOR PLAN
(ROOM HEIGHT 9'-6")



Hot water is used as the heating medium; the circulator is driven by a ¼ hp motor. The system was designed to operate at a maximum flow temperature of 130 F, and the automatic control governs the temperature of the water in accordance with the outside conditions, as follows: Hot water from the boiler passes along pipe *A* and enters the blender at connection *1*, while some of the return water from the circulating pump passes along pipe *B* and enters the blender valve at connection *2*. After the water is blended it passes over a thermostatic bulb in the blender to outlet *3*, where it is conveyed along the pipe *C* to the system. The thermostatic bulb is connected to the outside thermostat, the latter being sensitive to both air temperature and local low temperature radiation, but being screened from direct sun rays. If the combined effect of outside air temperature and low temperature radiation is increased in intensity, this acts on the outside thermostat, which automatically moves the valve to check the flow of hot water from the boiler and simultaneously increase the flow of return water direct from the pump—thereby reducing the temperature of the blended water flowing to the system. If the outside air temperature is reduced, or the radiation from the sun ceases, then the thermostatic bulb allows the valve to move in the opposite direction, thus increasing the flow of hot water from the boiler

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Greenville Steel & Foundry Co. Heats With Floor Coils

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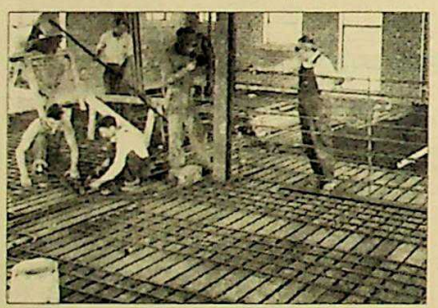
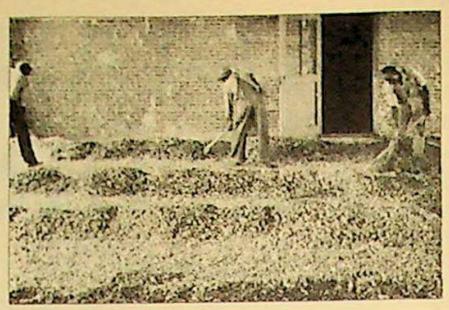
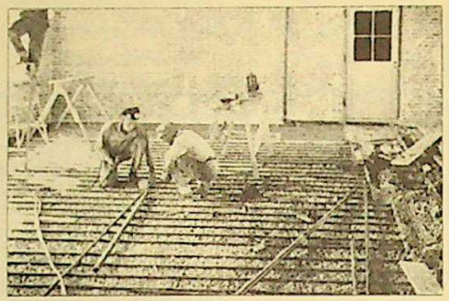
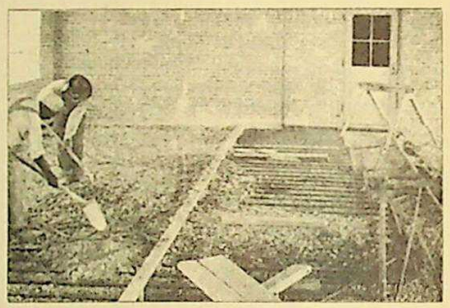


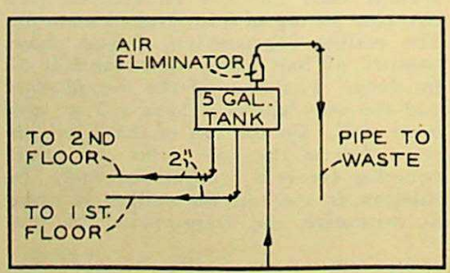
The construction used on the second floor. The prefabricated welded pipe grids were laid over cork insulation while the structural members supporting this floor are steel beams. The pipes were laid with a slight gradient to eliminate the air, and provisions were made for draining the coils when desirable. In designing this system, careful consideration was given to the permissible floor temperature. In order to prevent hot spots the pipes forming the grid coils are ¾ in. throughout. Larger pipes are used for the main circulation to which the various grids are connected. The ¾ in. pipes forming the grids are spaced on 8 in. centers. This gives a perfectly even surface temperature throughout. One of the principal reasons for using small diameter pipes when embedding them in plaster or concrete is that they are less likely to cause cracking if the temperature of the water should go too high







Successive stages of construction of the first floor. Broken stone was first laid on the ground and the pipes carefully laid on the foundation. Additional broken stone was then placed around the pipes, and a concrete slab about 2 in. thick was poured in order to form the finished floor



With such a system it is essential to eliminate all air from the water before it passes to the various pipe coils. To do this efficiently a tank was installed at high level with an automatic air eliminator

Construction Details for RADIANT HEATING AND COOLING

J. Napier Adlam Describes Installation at Northwestern Technological Institute

THE special radiant heat panels installed in one of the large classrooms at the new Northwestern Technological Institute, Evanston, Ill., where Prof. B. H. Jennings hopes to obtain some very valuable information on both radiant heating and cooling, should be of considerable interest to architects and heating engineers. The total panel surface provided is sufficient to allow several panels to be cut out as desired, so that the relative effectiveness of the different locations may be studied. A large portion of the floor area is to be heated with three wrought iron pipe coils embedded in the concrete, while six large metal panels will provide heat on the side walls and ceiling.

Prof. Jennings has, during the last four or five years, carried out a number of experiments in this field at Lehigh University, Bethlehem, Pa., and with these added facilities now at his disposal he hopes to obtain some very practical information which will

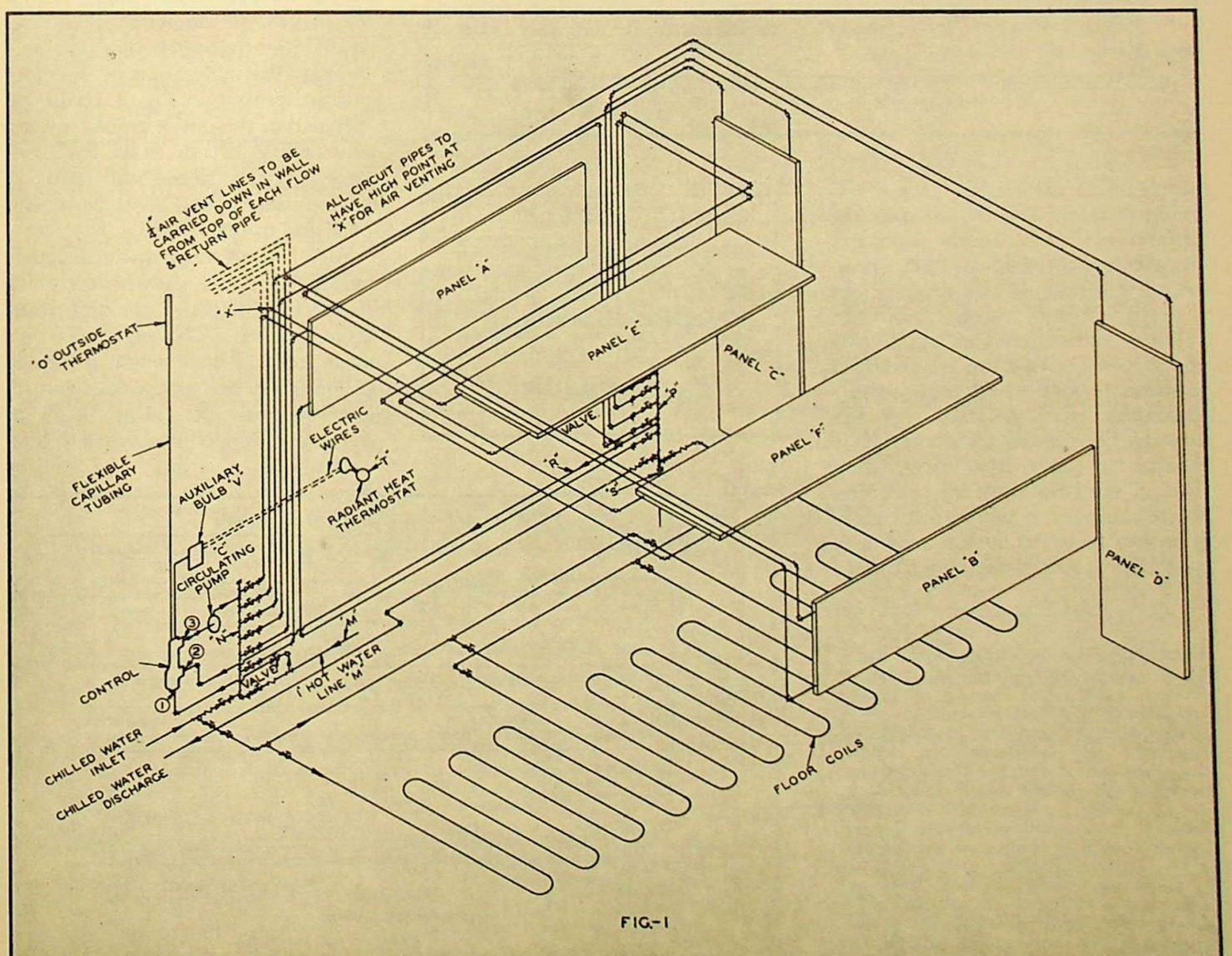


FIG.-1

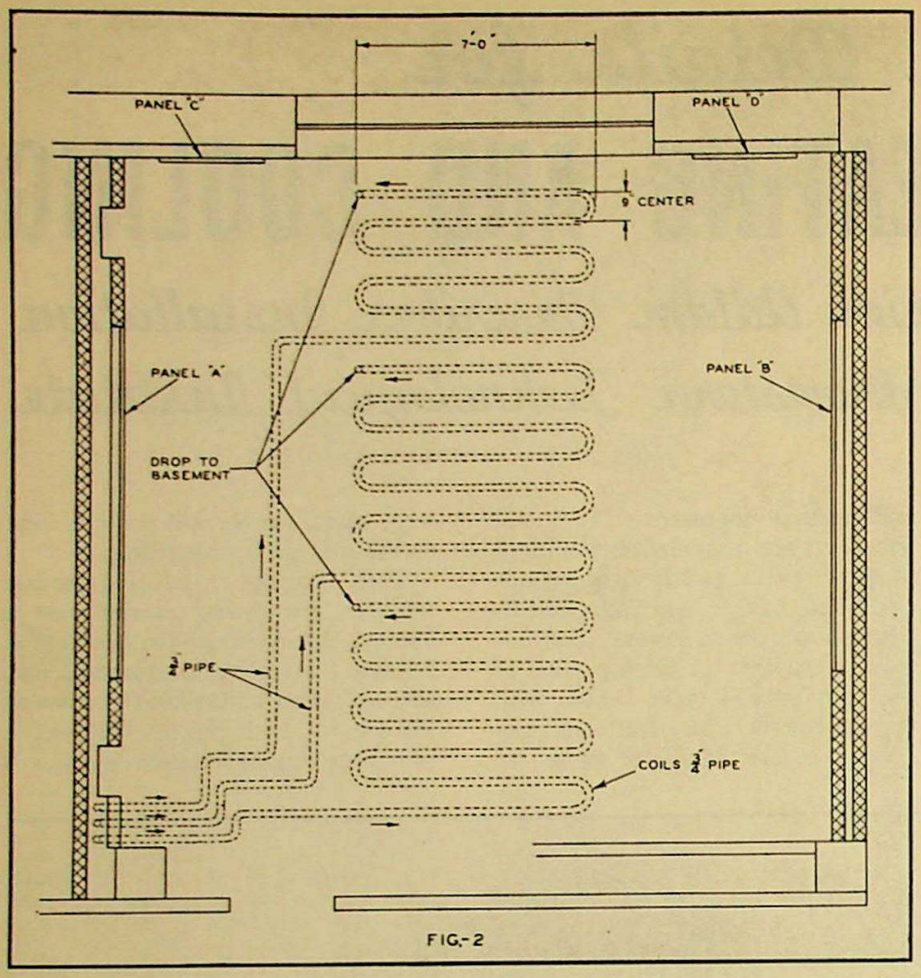


FIG.-2

be useful to the trade. One of his main objects will be to discover the difference, if any, in the efficiency of panels according to their positions. He intends also to carry out a series of tests to determine the value of radiant cooling and to discover how far this can be extended to promote comfort without meeting difficulties with moisture. It has already been established that it is possible to reduce the refrigeration load in summer time by providing cooled surfaces to increase the radiation loss from the human body, and it is hoped that some reliable data will be forthcoming from Northwestern Tech.

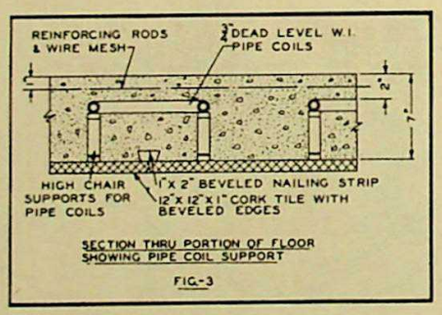

REINFORCING RODS & WIRE MESH
¾" DEAD LEVEL W.I. PIPE COILS
HIGH CHAIR SUPPORTS FOR PIPE COILS
1" X 2" BEVELED NAILING STRIP
12" X 12" X 1" CORK TILE WITH BEVELED EDGES
SECTION THRU PORTION OF FLOOR SHOWING PIPE COIL SUPPORT
FIG.-3

Fig. 1 illustrates the general layout of the panels and also the connecting pipes from the main hot water heating circulation. Panels *A* and *B* are placed opposite each other at high level on the two side walls, respectively; panels *C* and *D* are both placed on one end wall in a vertical position; while panels *E* and *F* are placed on the ceiling. Isolating valves are installed on both the flow and return circuits to each panel so that all or any of the panels may be shut off as desired. Connections are also provided to circulate chilled water through the coils.

An automatic control is provided to maintain the correct water temperature circulating through the panel coils, according to the outside weather conditions.

Fig. 2 illustrates the three ¾ in. wrought iron pipe coils embedded in the concrete floor, and Fig. 3 shows the method of supporting the coils in the floor construction. It was thought desirable to provide more positive venting in Fig. 2, so during installation the outlet points instead of dropping directly to the basement were run over to the wall partition behind panel *A* and vents were supplied for use if needed.

Fig. 4 gives constructional details of panels *A* and *B*, which are installed lengthwise on the side walls at high level. The pipe coils are made from ¾ in. wrought iron pipe and the pipes are spot welded at 4 in. intervals to the No. 11 ga, 0.125 in. steel plate. Tapped bosses are welded

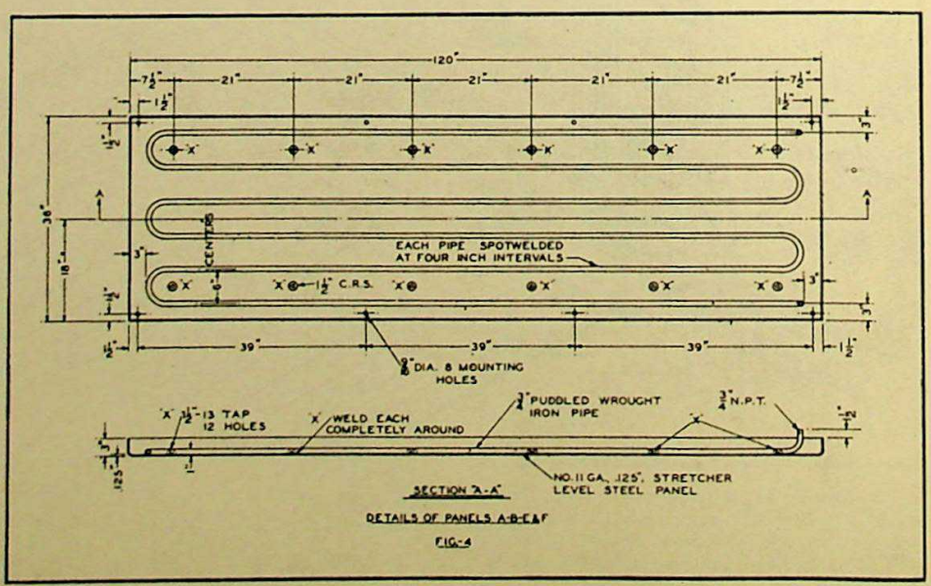


FIG.-4

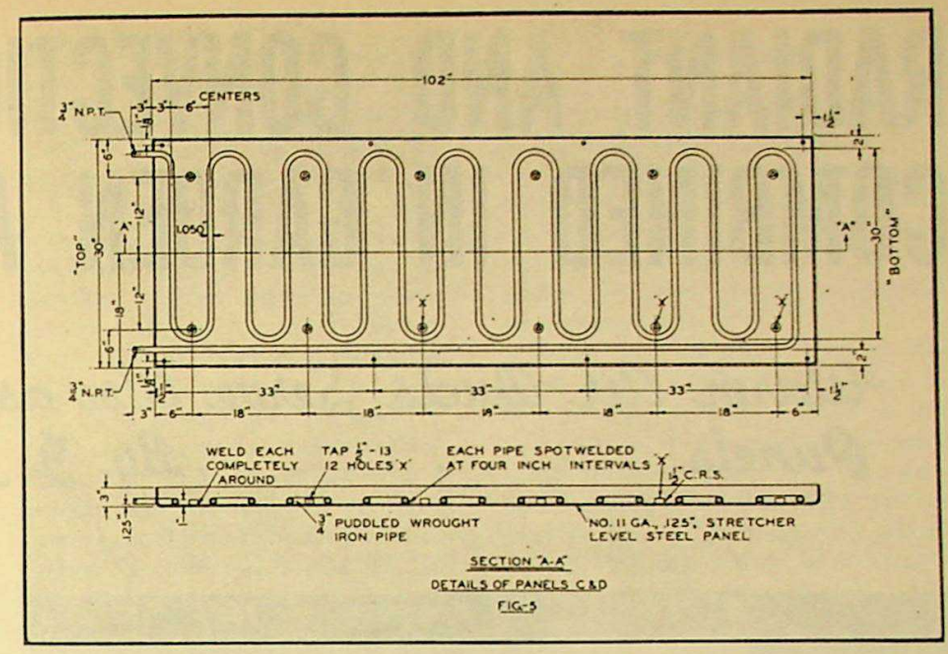
RADIANT HEATING—a subject which almost seems to require an "all-out" effort to satisfy the demand of heating engineers for data and information—is to be studied at Northwestern Technological Institute's new building. Mr. Adlam, vice-president of the Sarco Mfg. Corp., describes the special panels installed in one of the large classrooms there, from which it is expected valuable and practical data on this method of heating and cooling will be obtained. . . . Details of the panel construction are well illustrated in the series of drawings. An automatic control valve will provide the proper temperature of water circulated through the coils, in accordance with the weather

to the plate at points *X* to make provision for attaching the insulating pads.

The steel panels were fabricated from special stretcher steel plates with return ends formed to give a neat appearance. The surfaces of the iron panels are perfectly flat and will be painted to harmonize with the decorations of the room. Eventually, however, it is planned to make other experiments to ascertain the effect of covering the metal surface with a thin veneer of wood and other material. It will be noted that the pipes for these panels are placed in a horizontal direction to give free access for air venting at high level.

Figs. 6 and 7 show the method of mounting the insulation pads to the back of the panels to reduce the transfer of heat to the walls or ceilings. With panels *C* and *D* the circulating pipes are installed on the surface of the walls, whereas the pipe coils for the other panels are connected through the walls and ceiling respectively.

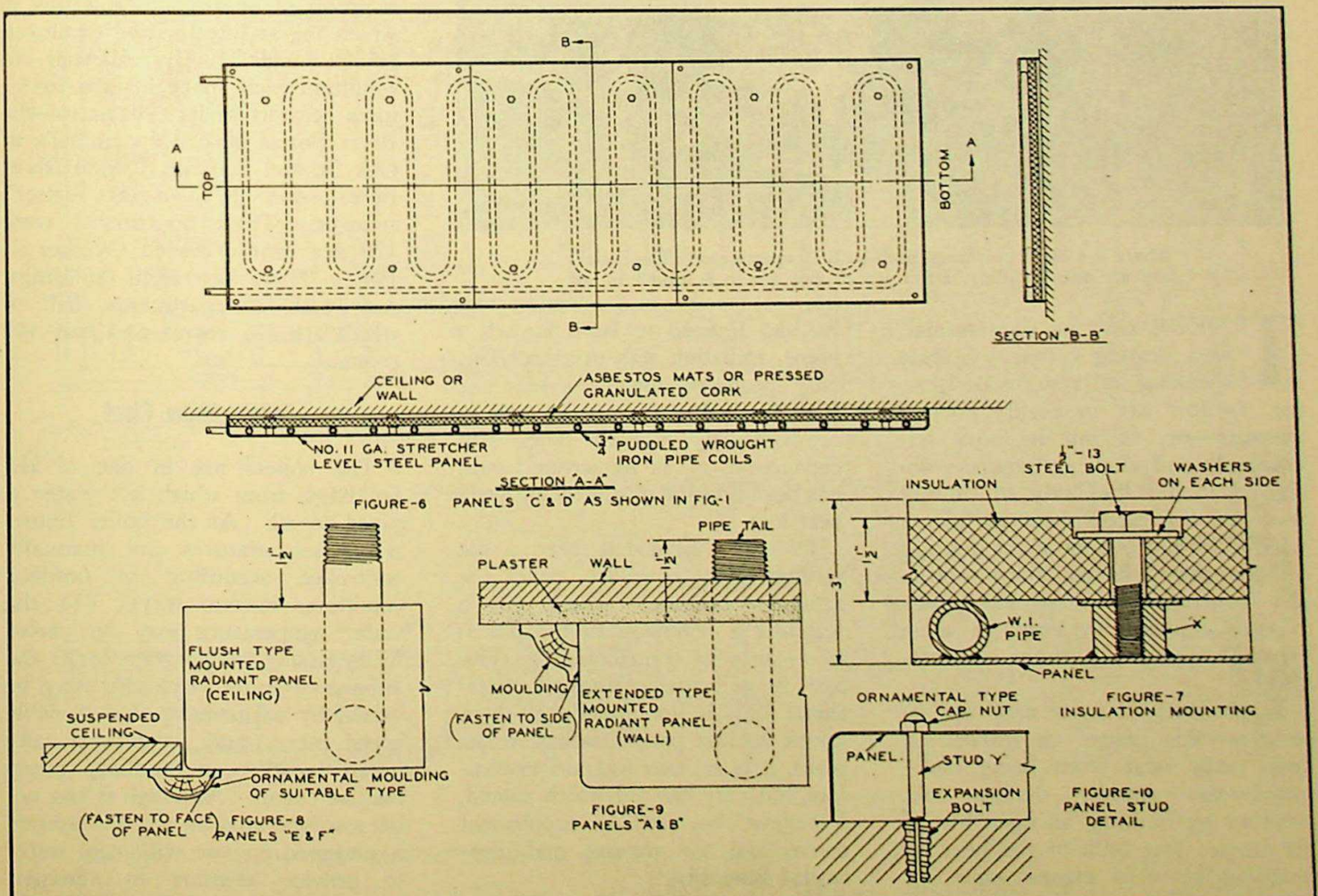
Fig. 8 shows the method of placing a wood moulding over the space between the plaster of ceiling and the



panels *E* and *F* to give a neat finish and prevent darkening of the surface. Sufficient space is provided to allow expansion of the metal panels without damage to the plaster; and the wood moulding which is fastened to the face of the panel slides over the surface of the plaster quite freely.

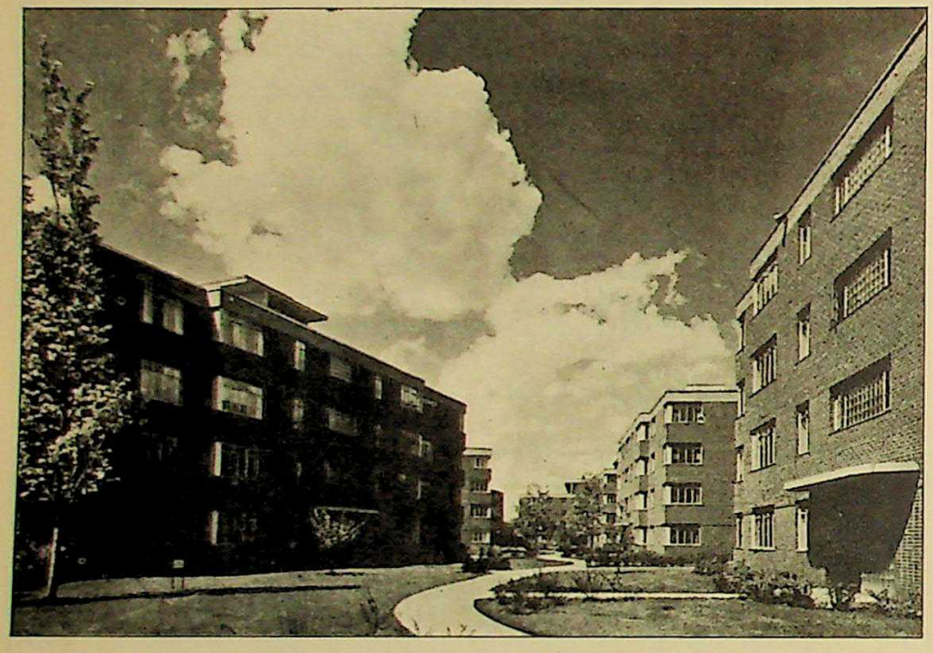
Fig. 9 shows the method of applying a moulding around the joint where the metal panel makes contact with the surface of the plaster on the walls. In this instance the wood moulding is fastened to the side of metal panel, so that the moulding may slide easily over the surface of plaster.

Fig. 10 illustrates the method used for securing the panels to the walls and the ceiling.



RADIANT AND CONVECTION HEATING COMBINED IN GARDEN APARTMENTS

Warm Air Ducts Serve Also as Ceiling Heat Panels . . . . . By G. F. Nightingale



There are eight buildings, each with 16 apartments. The boilers are in one building, from which hot water is piped to all

RADIANT AND CONVECTION heating are combined in the system serving the River Forest garden apartments in suburban Chicago. Hot water from a central boiler installation is piped to a standard unit serving each apartment. From the unit warmed air goes through ducts to ceiling air diffusers. The ducts and portions of the metal ceiling serve as radiant heat surfaces, thus combining these two methods. . . . Mr. Nightingale, western sales manager for Tuttle & Bailey, Inc., describes the layout here, and reports the results of a brief tenant questionnaire

THERE ain't no such animal" as a heating system. Strictly speaking, all systems designed for comfort are in reality cooling systems—or, to put it more scientifically, all such systems are designed to aid the body in ridding itself of its excess heat at a rate which will not put too great a strain on the very efficient thermostatically controlled arrangement which Nature devised to keep us alive (though not at all times comfortable).

In the early days of man's existence on this planet, he learned to keep body heat from being dissipated too rapidly during cold weather by building an open fire in his cave. The bulk of the heat he received by this means came by radiation. For centuries, even after he had learned to build himself a home, radiation was practically his only means of controlling heat loss from his body. It has been only in comparatively modern times that convection, in its numerous forms, has been a factor in controlling body heat loss.

Of late, there has been a lot written about so-called "panel (or radiant) heating," which (in a way) is a reversion to the primitive—since its contribution to comfort is principally through radiation. This is not intended to be a knock against panel heating; in its place, it is an excellent aid to comfort, but only one aid which should, I believe, be used to supplement convection, air motion and controlled humidity.

We have in a suburb of Chicago, a group of apartment buildings in which the architects have employed all four aids, nicely balanced, to condition each space for the maximum comfort of its occupants—the River Forest garden apartments, at Oak St. and Harlem Ave. in River Forest, one of Chicago's "better" suburbs. These apartments were 100 per cent occupied October 1, 1940. There are eight buildings, each with 16 apartments, half of which are 3½ rooms and half 4½ rooms.

Central Boiler Plant

The boilers are in one of the buildings, from which hot water is piped to all. At the boiler house, water temperatures are manually controlled according to outdoor conditions in two ways: (1) the water temperature may be varied by bypassing return water; (2) the volume of water circulated may be varied by adjustment of a variable speed pump, and in exceptionally severe weather an auxiliary pump may be cut in. Although it has not been so operated as yet, the system is designed for use with cool water to provide comfort in summer. Each apartment may be individually

controlled by its separate thermostat; this is extremely important, since few individuals require the same conditions for maximum comfort.

Referring to the floor plan of a typical 4½ room apartment, hot water is piped to a unit situated as shown. This unit is a standard make consisting of a fin type radiator through which air is passed by a standard blower. The air then goes through ducts *A* and *B* to ceiling outlets in the living room and dining alcove and through other ducts to registers in the bedrooms, bathroom and kitchen.

Panel Heat Surfaces

The ceilings have steel veneer surface, attractively painted. Across the living room and the dining alcove, the bottom sides of the ducts form heating panels 9 in. wide by 18 ft for duct *B* and 9 in. by 7 ft 6 in. for duct *A*. These panels are somewhat enlarged by conduction of heat through the steel ceiling. There is also a secondary pair of panels in one bedroom, through the ceiling of which pass the ducts *A* and *B*. Furthermore, some heat from these same ducts passes upward through the concrete slab to the floor of the apartment above (except, of course, on the upper floors). Panel heating is thus provided by these warm air ducts.

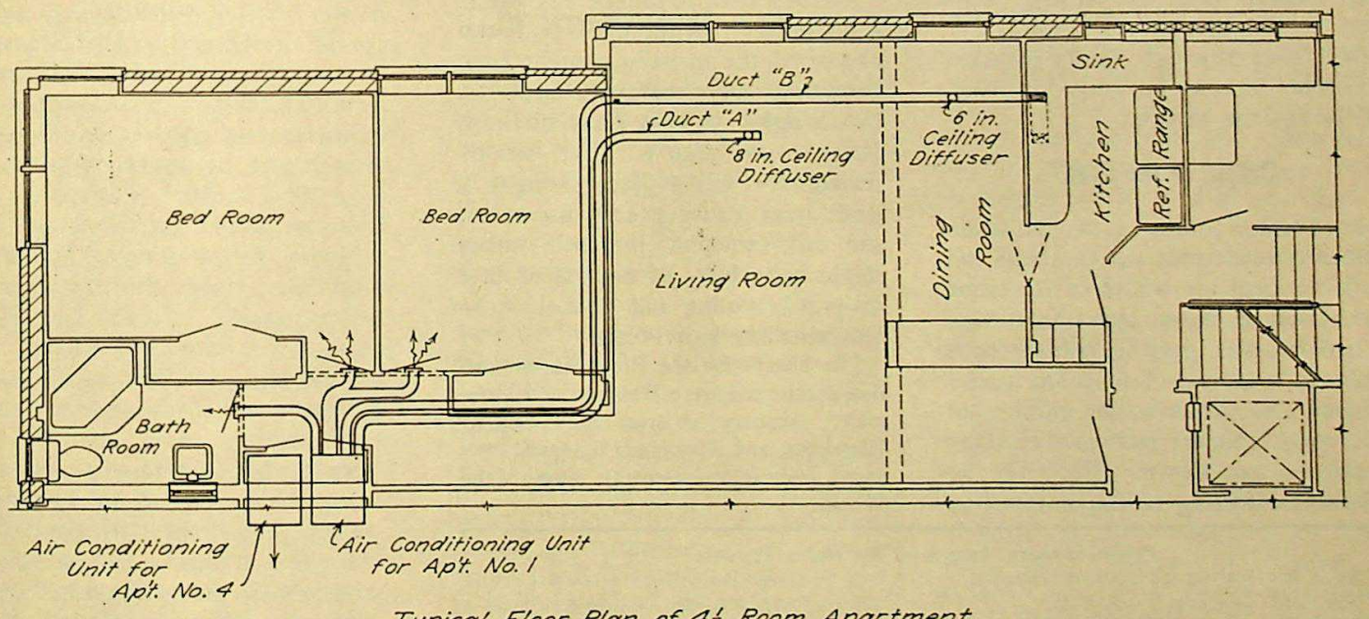
A lot of thought was given to the location of the ceiling outlets themselves. At first, it was felt that a location near the center of the room would give the best results but after careful consideration, it was decided to place both ducts and outlets fairly near the windows, in order to blanket the windows with warm air and also to get the heat radiating surfaces as near the point of maximum heat loss as possible without sacrificing comfort in the back of the room.

Tenant Reactions

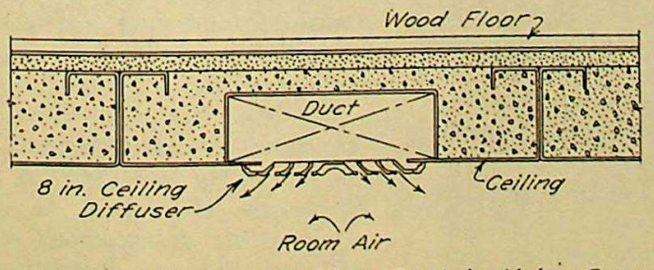
A questionnaire was submitted to three families (selected at random) living in the apartment group. Family *X* comprises two adults and two children; family *Y*, two adults and one child; and family *Z*, two adults. Family *X* occupies a northwest apartment.

Note that all three report the same setting of the thermostats in cold or mild weather. This would not be true if the apartments were uncomfortably cool in s e v e r e weather. It is natural when we feel cool to try to do something about it and that something is invariably to push up the thermostat. The fact that all three families do not vary the setting during severe weather shows in itself that each is comfortable at the temperature which each selected.

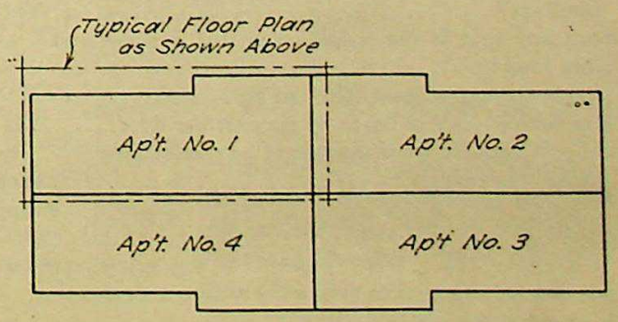
Replies given by family *X* are interesting. Note that their apart-



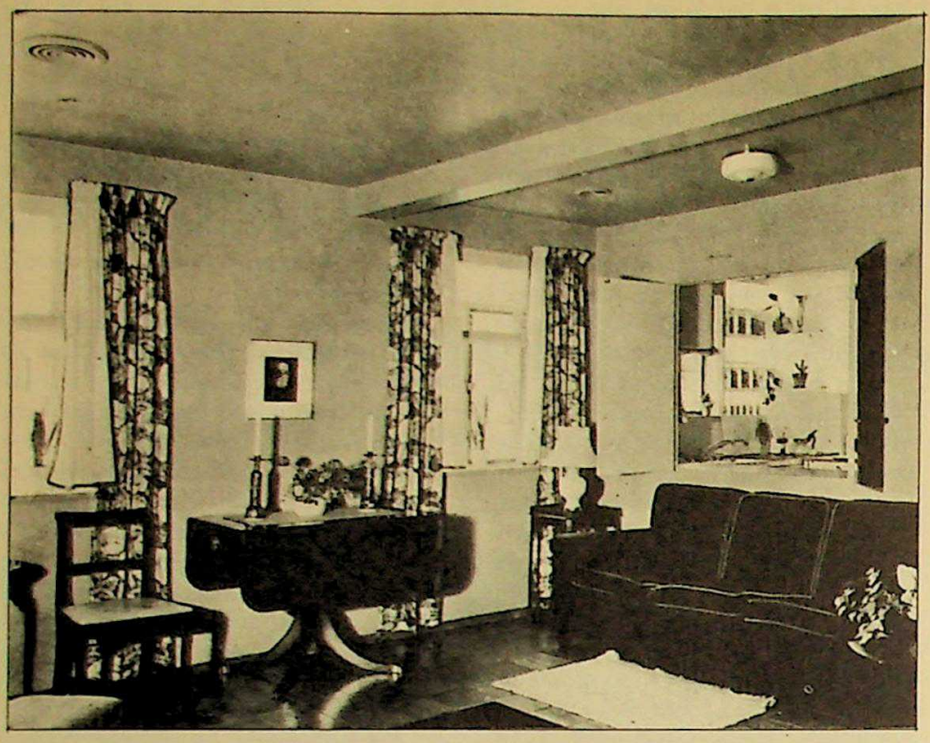
Typical Floor Plan of 4½ Room Apartment



Section Through Ceiling Duct in Living Room



Typical Floor Plan



Living room of one of the apartments (with a peek at the kitchen), showing the ceiling air diffusers

ment has a northwest exposure and that except when the wind is high, they report themselves comfortable. Infiltration through faulty window construction may be—but not necessarily is—the answer.

Caught in the Draft?

In another building, a gentleman without much hair on his head sat under a cool air outlet of the same type used in these apartments and swore he was getting cold from a draft on his head. Tests with smoke showed no downward motion of air; what little air motion there was went up, not down. Probably he did have a feeling of discomfort due to radiation to the diffuser above.

Getting back to family *X*, there is a possibility that the individual who answered the questions might have been unusually sensitive to heat loss by radiation to cold glass surfaces. In that case, like our bald headed friend, she might have thought a draft was causing the discomfort she felt, whereas the true cause might have been an unplanned case of panel cooling not noticeable to less sensitive individuals.

[Architects for the River Forest garden apartments were Holsman and Holsman; heating contractors, Economy Plumbing and Heating Co.; and sheet metal contractors, General Sheet Metal Works.]

Questionnaire Answered by Three Tenants

	X	Y	Z
What is the setting of your thermostat?			
In cold weather	76	72	70-75
In mild weather	76	72	70-75
In cold weather, do you avoid sitting near the windows?	Yes	No	No
Is there any spot in the living room that is uncomfortably cool?	No	No	No
Do you ever experience cold feet?	No	No	No
Do you permit your children to play on the floor?	Yes	Yes	Yes (guests)
Would you classify your apartment as comfortable during the winter?	Except during high winds	Yes	Yes
Do you notice any spot in this room where a draft is noticeable?	No—except near windows	No	No

WHY PANEL HEATING?

THE EDITOR—

Having noted with interest how certain recent letters on this page have drawn fire from antagonist and protagonist, I ask the privilege of tossing in a question regarding that type of heating which is currently getting much publicity and which in its various forms is known as radiant heating or panel heating.

One reads the most scientific analyses of the principles of radiant heating by some of our most able physicists, and one sees impressive photographs of installations in buildings bearing the names of the country's leading architects; but does not this question arise in the mind of others as it does in mine—*why?*

Why is it that after years of evolution and improvement of convection or semi-convection heating, after great effort to perfect methods of control, and after having arrived at reasonably satisfactory methods of calculation, are we suddenly presented with the radiant heating method—with the implication that it is the perfect method, or at least better than those we have used?

It would be appropriate for someone to present a case for radiant heating, demonstrating whatever real advantages it may have before too much effort is wasted upon its study.—J. H. WALKER, superintendent of central heating, The Detroit Edison Co.

F. W. Hutchinson Presents a Part of the Case for Panel Heating . . . Opinion *Pro* and *Con* Requested

PARADOXICALLY, the rapid acceptance of low temperature panel heating in Europe was probably largely due to a characteristic of the system which, in terms of effective heating, is inconsequential; the English and continental home owner and architect are strongly averse to any visible form of heating surface and were therefore ready and willing to adopt a form of heating which provides adequate warmth while remaining completely invisible. Thus, the impetus responsible for the prompt acceptance of low temperature radiant heating abroad apparently was derived from architectural rather than engineering advantage.

However, as the number of panel installations increased and operating data became available, a number of specific engineering characteristics of panels came to the foreground and increased attention was given to radiant heating by engineers and heating specialists. Most significant of these observations was that with low temperature heating panels in the ceiling a condition of substantial comfort can be realized in a room with air temperature lower than that needed when radiators or warm air grilles are the sources of heat. The extent to which a reduction in air temperature is possible depends upon the construction of the building and the outside temperature, but European experience has shown that a reduction of 5 to 8 F is not unusual.

Humidity Indoors

Aside from the obvious economic advantages of reduced inside air temperature — lower heat loss due to infiltration or to ventilation and, in some cases, reduction in transmission losses—there seem to be certain intangible advantages in terms of comfort and health. Among these are said to be higher indoor relative humidity, without use of a humidifier, and a feeling of increased "freshness" of the air.

The effect of lower temperature on relative humidity can be easily visualized by referring to the simplified psychrometric chart reproduced here. If saturated outside air at 40 F (point *a*) were heated to 72 F (point *b*) the resultant relative humidity would be 32 per cent, while if heating ceased at 62 F the relative humidity would be 45 per cent (point *c*). Then, for an outside condition as assumed, each degree reduction of the inside air temperature is responsible for an increase of approximately 1.3 per cent in the indoor relative humidity. The magnitude of this term is clearly a function of the absolute humidity only and the effectiveness of lower room air temperature as a means of increasing relative humidity therefore varies directly as the outside temperature and the outside relative humidity.

In cold weather the improvement due to inside temperature reduction is slight (0.1 per cent per degree for 10 F, 100 per cent relative humidity outside) while at moderate outside temperature the effectiveness is pronounced (1.9 per cent per degree at 50 F, 100 per cent).

The above characteristic is in part advantageous, but it also represents a distinct disadvantage. Since moderate temperatures exist for a relatively large fraction of the heating season the value of decreased drying of the inside air is realized over the longer interval; but when the outside temperature becomes very low—the time when "drying" of the inside air is normally most severe—the value of panel heating as a means of raising the relative humidity is practically negligible.

Air Temperature

Effects on health or comfort of inside air temperature cannot be stated with exactitude. Within the limits of present knowledge it is possible only to call attention to some observed effects and to conditions which are believed to be of significance.

More important than the actual

inside air temperature is the difference between inside and outside temperatures and the resultant "shock" experienced by the occupant as he leaves a heated room. In a warm room the membranes of the nose are seemingly flooded with blood and lymph and covered with a thick secretion; when sudden chilling occurs the blood vessels of the nose constrict, reducing the blood supply and lowering the temperature of the mucous membrane which remains swollen with lymph. Some authorities believe that this anemic condition of the enlarged membrane is conducive to infection. With radiant heating the internal membranes of the nose are subject only to energy transfer from the cooler room air and the anemia resulting from sudden exposure to low outside temperature should therefore be reduced. The quantitative significance of this factor cannot now be evaluated.

WHY PANEL HEATING?, a question asked in a letter published in the September HPAC, is discussed here. The intent of the author, who is assistant professor of mechanical engineering at the University of California, is to review some of the intangible factors which influence the selection of a given type of heating system and to show from psychrometrics, and by reference to current ideas regarding "freshness" of air in an enclosure, the background for some of the claims which have been advanced for panel heating. . . . Possible improvement in the indoor relative humidity (without use of a humidifier) is shown to be negligible during very cold weather, but quite pronounced for moderate outside conditions. . . . Cooler room air reduces the "shock" of leaving an inside warm environment since the danger of anemia of the mucous membranes of the nasal passage is reduced; however, no quantitative significance can yet be assigned to this effect. . . . Since the heating surfaces in a panel warming installation are at a very much lower temperature than are the surfaces used with other types of heating systems, the "baking" effect on the air is reduced, and there is reason to believe that this factor may be significant in improving the degree of "freshness" which can be realized in a closed space.

Ion Content of Air

It is generally recognized that there is some vitalizing property of outdoor air which has not yet been duplicated indoors. Many observers believe that this property may be associated with the ion content of the air. Ions are positively or negatively charged molecule clusters and are roughly classified as large or small. In nature they are produced by cosmic rays, solar radiation and by radioactive elements in the soil; their production artificially can be accomplished by electrical means and equipment for this purpose is available commercially.

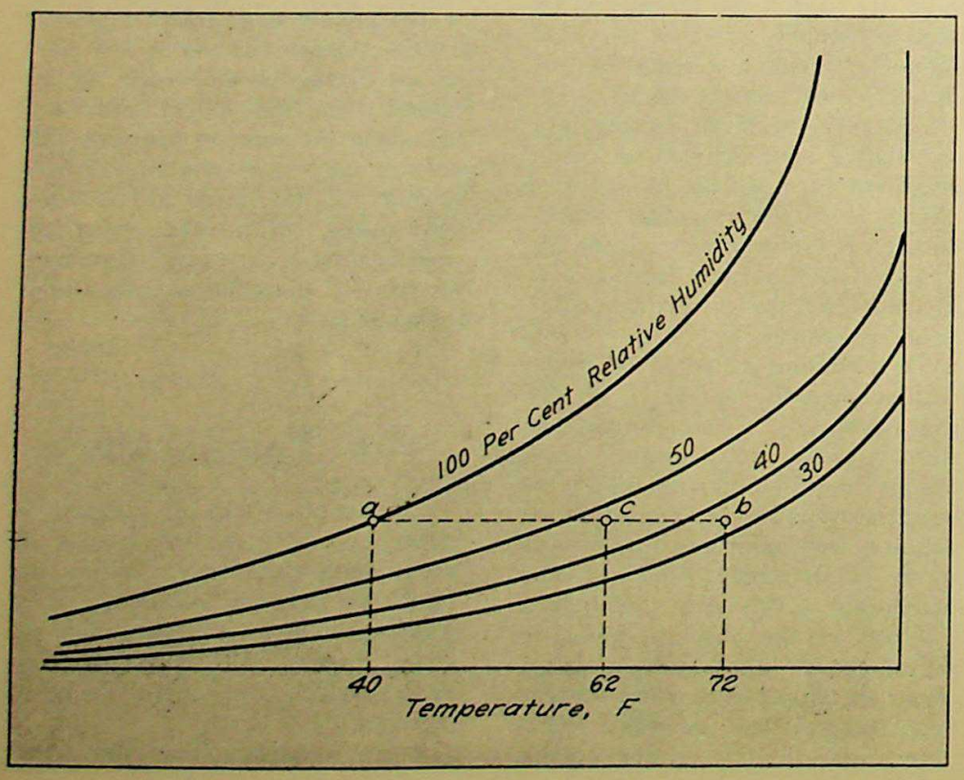
Present ideas concerning the effectiveness of ions in producing either "freshness" or "stuffiness" are vague, but two vital facts are evident: (1) The passage of outside air through ventilating ducts and through heating or air conditioning equipment is responsible for material changes in the ion content of the treated space. (2) A preponderance of small positive ions is known to have an adverse effect on the ability of the occupants to think clearly and is responsible for headaches and nose irritations. Small negative ions; on the other hand, predispose to relaxation, increase mental activity and have other desirable characteristics.

The whole subject of ionization is in such a vague state that it is not now possible to say what value, if any, may eventually accrue from deliberate control of ion concentration by artificial means. The importance of the subject to present day heating and air conditioning derives from the fact that equipment now in use is itself a factor in the determination of the ionic state of the conditioned space.

Radiant heating is designed to establish comfort with a minimum of air heating and such heating as does occur results from contact of the air with a surface at much lower temperature (90 to 100 F) than is customary with other systems. Therefore panels might be expected to have less of a "baking" effect on the air in the room and effect to a minimum the ion content.

European experience seems to demonstrate that a greater feeling of "freshness" is experienced in a panel heated structure than in one heated by straight convection. Limited experience in this country leads to the same result. Whether this is a result of the ionic state, or, more simply, due to lower air temperature is not known. In this connection it is interesting to note that Dr. Bedford, in summarizing the results of a study on subjective impressions of freshness, lists seven requirements for a pleasant and invigorating atmosphere; the first of these requirements is that the room be as cool as is compatible with comfort.

Simplified psych chart



THE EDITOR—

I have read with considerable interest F. W. Hutchinson's article in the October HPAC on this subject of panel or radiant heating.

After many years of experience with radiant heating, I agree with Mr. Hutchinson that with radiant heat a room temperature of 5 to 8 F lower than is normally set for convected heat is found to be perfectly comfortable, provided the radiant panels are sufficient in quantity and correctly located. It may be that some installations can be found that do not substantiate this, but I venture to say that any radiant heat system which will not give equal comfort conditions at a lower air temperature than that necessary by a convected heat system has been provided with insufficient or faulty radiant surfaces which do not take care of the radiation from the human body. This protection against radiation loss is the greatest factor on the side of radiant heating and is the main reason why we can have a lower air temperature and feel perfectly comfortable.

In addition to this, however, there is a distinct advantage because of the higher relative humidity which is a consequence of a lower air temperature. In cases of extreme temperatures, this higher relative humidity may not appear to be very substantial, but even a small percentage of increase at such extreme temperatures will make quite a lot of difference to human comfort.

There is, I think, another important factor which must be taken into consideration and that is the metabolism of the human body. It seems to be well established that as the temperature of the air is lowered, a greater chemical action takes place within the body and more heat is produced. In other words, the fire within burns more brightly and heat is generated more rapidly as the temperature drops to 60 F than is the case where the air temperature is high. According to the best information available it seems to be substantiated that with a high air temperature the organs of the body relax, especially those organs generating heat; consequently, a smaller amount of heat is generated, which explains the reason why some people often feel chilly in a room temperature of 80 F or above. With a properly installed radiant heat system with sufficient radiant surfaces, it is found that the human body can function more correctly and generate sufficient heat to maintain a very comfortable condition with air temperatures as low as 58 to 60 F.

An English medical research committee, after a number of exhaustive tests and investigations, came to the conclusion that the agility of students is much higher and a greater activity of the mind and muscles is shown in a cooler atmosphere with radiant panels to protect the body against too much radiation loss. Therefore, I think we must look to this function of metabolism for one of the reasons why the body can be comfortable with a much lower air temperature. — T. NAPIER ADLAM, Sarco Co.

THE EDITOR—

I read with keen interest all the letters in this column, for here is where the average man can make known his likes and dislikes. I noted a letter from J. H. Walker in September in which he asked "Why panel heating?" The same question has been in my mind for some time —*why?*

If all you are after is heat with no humidification or ventilation, then of course a panel installation is fine. However I think panel heating is a definite step in reverse. What we are after is cleaner, more healthful air in our buildings, along with body comfort. It makes no difference whether it be for summer or winter, if we are to get such a condition we cannot use the panel method. Some wise guy is going to say use a split system. What for? Why not do the job correct in the first place?

One other point has been bothering me on this subject. Whenever mention is made of panel heating the article is usually headed "Panel Heating and Cooling," but nothing is ever said about the cooling cycle. How come? I'll tell you why no one mentions it. It is a flat failure. I make this statement from actual experience. You can cool by the panel method but it had better be a meat storage house and not a building where humans are going to live and work.

If we are going ahead, let's forget all about panel heating and cooling and sell our country's buildings year 'round air conditioning using plenty of outside air—filtered, cooled or heated, humidified or dehumidified, to give real healthful comfort. —WILL D. SAMPSON, consulting engineer.

THE EDITOR—

In his letter published in the September HPAC, J. H. Walker suggested that someone demonstrate whatever real advantages panel heating might have.

Our experience with panel heating is confined to three local installations employing ceiling panels exclusively. The first installation designed by us was made locally in 1938 and has been through three winters' operation. The second installation, made in our own test house in 1940, has been through one winter of operation. The third installation, in the home of one of our officers, made this year, has not completed a full year's operation.

The test house was built expressly for the purpose of developing data for application of the system. It is an eight room, unfurnished, unoccupied house—equipped with 175 thermocouples and instrumentation for recording essential data. The opinions expressed below are based primarily on observations made at this test house.

Uniformity of Temperature—A drastic reduction in the temperature variations that were accepted years ago has resulted from better heating systems and better construction. Nevertheless, the modern, intermittent, automatically controlled system of convection heating develops a variation between the end and beginning of the "on" period sufficient to have given birth to the term "cold 70."

With forced hot water heating the water is delivered to the radiators at approximately 190 F until the thermostat is satisfied, when

water circulation ceases and the radiator or convector may cool almost to room temperature. With forced warm air the air is delivered through the grilles at about 145 F until the thermostat is satisfied, when air delivery ceases. These intermittent injections at relatively high temperatures cannot produce the uniform environment obtainable from a constant source of heat at temperatures controlled within a relatively close range. Even though panel heating may be intermittent in operation, the very nature of the system is such that wide temperature fluctuations in the heating panel are impossible.

In normal winter weather of + 24 F, the average ceiling panel temperature in the test house was 77.5 F. The low average panel temperature for any time reading during the 24 hours was 71.7 F at 2 p.m. after several hours of sun effect, and the high was 80.9 F at 6 p.m. after the loss of sun effect. This narrow range of 9.2 F in the heat source compares with possibly 120 F for convection systems. A heat source which blankets the entire room and is maintained within such narrow limits should definitely insure a more uniform environment.

Panel heating is a mass heating effect as compared with the concentrated heat source of conventional methods, the result of which on test reflected an average ambient temperature differential of the order of 0.7 F between the beginning and end of the "on" periods, which compares with 2 F or more for convection systems. Vertical gradients also show an improvement as indicated by the following average readings over a 24 hr period in 10 rooms: 68.8 F 6 in. above the floor, 70.5 F 5 ft above the floor, and 71.8 F 6 in. below the ceiling.

Constancy of Temperature — Throughout a panel heated room there is also a constancy of temperature apparently not obtainable with convection heating. As the heat loss of the structure increases with colder weather, the inner surface temperature of exposed walls is depressed, radiation losses from the body to these cooler surfaces increase, demanding higher air temperatures for comfort. This air temperature gradient with conventional heating systems may easily reach a magnitude of 8 F, which must be manually regulated by thermostat adjustment.

As panel heating is the reverse of convection heating in that the air is warmed from the walls, the mean radiant temperature cannot drop below the air temperature. Air in a panel heated room closely approximates the MRT and finds a comfort level at about 70 F. This 70 F mean radiant and air temperature level is maintained within rather close limits regardless of outdoor temperature.

An average of seven points in exterior walls of the test house at 2 a.m. (no sun effect) was 65.9 F with an outdoor temperature of + 14 F. At 11 a.m. (bright clear day) the same seven points averaged 70.8 F, the outdoor temperature having risen to + 31 F. An average of the seven points over a 24 hr period with an outdoor temperature of 24.7 F was 67.2 F. When the low exterior wall temperature was recorded at 2 a.m., the average floor temperature was 70.5 F and the ceiling 78.5 F. At 11 a.m., when the exterior walls rose to 70.8 F, the floor dropped to 68.9 F and the ceiling to 75.2 F. These two sets of conditions produced almost identical mean radiant temperatures and therefore no adjustment in the air temperature was necessary to maintain comfort.

Greater Comfort from Warm Floors—A stratum of cool air over a floor which is even cooler is not conducive to comfort. With panel heating, the floor is warmer than the air immediately above it as indicated by the following average readings: floor, 70.6 F; 6 in. above floor, 68.8 F; 5 ft above floor, 70.5 F; 6 in. below ceiling, 71.8 F; ceiling (the heating panel) 77.5 F; outdoor temperature, 24.7 F.

Cleanliness and Appearance— In addition to these "comfort" advantages, panel heating should contribute to cleanliness. There is no part of the system wherein dust can collect. Convection currents established by the heating system are extremely slight and therefore do not disturb dust that may be present. There is no discoloration of walls or ceilings which so frequently accompanies convection systems and no part of the panel heating system need mar the beauty of the living quarters or interfere with furniture placement or decorations.—H. F. Randolph, vice-president, International Heater Co.

The Editor—

I can't help expressing an enthusiastic "pro" for F. W. Hutchinson's article, Why Panel Heating, in the October issue. I feel that I can speak with some authority of experience, having lived with the system through a fairly severe winter in our new office building in Greenville, S. C.

To describe our installation briefly, wrought iron grid coils were laid on a broken stone fill on the ground floor level, and a concrete floor slab poured over. On the second floor level wrought iron coils were set on a 2 in. layer of cork under the concrete floor. Water heated by a standard boiler is circulated through the system at a maximum of 130 deg to maintain the proper floor temperature. [See HPAC, June, 1941, pp. 352-353.]

Reactions of the employees working in the building last winter seem to bear out the arguments presented by Professor Hutchinson. There were considerably fewer colds and one woman announced absolute freedom from sinus trouble which had bothered her considerably in the past. Men working at the drafting tables noticed less fatigue and there was a complete absence of the sluggishness which ordinary heating systems sometimes seem to cause when they are working at full intensity during cold weather.

It is impossible for me to surmise whether these reactions were caused by lower air temperatures, lack of drafts, proper humidity, or ion balance, as Professor Hutchinson's article suggests. I can, however, offer them as an example of one installation which has borne out all the claims made for the radiant or "panel" type of heating.—Dan H. Wallace, Jr., president, Greenville Steel and Foundry Co.

THE EDITOR—

The recent comments on this page regarding panel heating have been interesting and instructive. Professor F. W. Hutchinson's article in October ably sets forth the advantages of the method as recognized in England.

There seem to be one or two points that should be clarified. One of these concerns definitions and terminology. There is a tendency to refer to panel heating and radiant heating as being synonymous; actually they are not entirely so. A panel heater, being a flat surface, emits a larger part of its heat by radiation than if the same surface were crumpled up into the form of a conventional radiator or convector, in which much of the surface is shielded from view. But a panel heater does not ordinarily heat *entirely* by radiation; in fact, it would be difficult to design a system of purely radiant heating because the temperature of the room air eventually tends to rise, as the floors, walls and furniture become warmed. The nearest approach to pure radiant heating is to place the heaters overhead and thus minimize the convection effect.

A second point of confusion is in regard to the benefits of a lower air temperature. Naturally the more radiant heat the lower will be the effective temperature necessary for an equivalent feeling of warmth. However, heat loss from the clothed human body takes place first to the air space inside of the clothing. It is doubtful that radiant heat, of the amounts and wave lengths which we are considering, penetrates the clothing appreciably. Therefore, as to most of the body surface the body probably "doesn't know" whether it is in an environment of lower temperature and more radiant heat or of higher temperature and less radiant heat.

T. Napier Adlam's comment in November regarding the effect of radiant heating upon metabolism does not appear to me to be well-grounded. Mr. Adlam states that metabolism rises with decreasing temperature and that such increase in metabolic rate is beneficial. Is it not assumed that with radiant heating the overall feeling of warmth will be unchanged, and if so how can we assume an increase in metabolic rate? Furthermore, Winslow and his associates have reported[1] that they found no appreciable change in metabolic rate over a considerable range of temperature.

H. F. Randolph presents above some interesting factual information. He scores some telling points when he shows the low temperature of the heating surfaces and by his statement that "A heat source which blankets the entire room and is maintained within such narrow limits [of temperature] should definitely insure more uniform environment."

Methinks, however, that he oversells panel heating when he compares it with forced hot water using a temperature of 190 F and forced warm air using a temperature of 145 F. A forced hot water system is not necessarily designed for 190 F. Such a temperature is no more fundamental in a hot water system than it is in a panel system. The use of larger radiators reduces the temperature necessary in extreme weather; and in any case intelligent operation calls for temperatures which are graduated in accordance with the outside temperature. Panel heating should be compared with the best practice in other fields, not with the worst.

No one will deny that there are certain advantages in panel heating. To avoid cold floors in a building having no basement, to counteract the negative radiant effect of large expanses of windows, and for other special purposes, panel heating is undoubtedly advantageous. From the physiological standpoint there *may* be distinct advantages, but they certainly require much further study before they can be stated as established facts.

The danger is that the panel method will be exploited and oversold upon the basis of half-baked or wholly fictitious talking points which the public has no means of verifying or disproving.

What is needed right at this time is additional research in laboratories and some critical examinations of the performance of existing installations so that the advantages and limitations can be clearly understood and made known.—J. H. WALKER, superintendent of central heating, The Detroit Edison Co.

[1] Physiological Reactions and Sensations of Pleasantness Under Varying Atmospheric Conditions, ASHVE Journal Section, HEATING, PIPING AND AIR CONDITIONING, January, 1938. See also the Heating, Ventilating, Air Conditioning Guide 1941, p. 43.

THE EDITOR—

It was with considerable interest that I read J. H. Walker's comments on panel heating on pp. 751-752 of the December HPAC. It seems to me, however, that there still exists a certain amount of confusion on this subject because many people continue to look upon radiant heating as simply another method of heating a building, instead of studying its effect on the human mind and body. I notice that Mr. Walker suggests that with radiant heating the overall feeling of warmth will be unchanged, but, in my opinion, we do not need a feeling of warmth. When the conditions are such that we have no feeling of either heat or cold, the state of the body will be more tranquil and the mind will not be conscious of any kind of strain on our thermostatic system. If the body loses more of the dissipated heat by radiation and less by convection than our thermostatic system is ordained for, then the mind is undoubtedly conscious of a strain, whether the individual knows the reason or not.

Everyone has undoubtedly experienced at various times the mental stress which takes place when finding himself trying to work in an atmosphere where the air temperature is too high; and again, most people have experienced that extra agility and alertness which develops when one is working or walking in a nice sunny place where the air temperature can be considered on the chilly side. I think it is sufficiently well established for me to say with confidence that it is the radiant energy direct from the sun, plus the cooler and longer wave length rays reflected from surrounding objects, which protect the body from too much heat loss; and that it is the cooler air which creates alert-

ness and promotes the extra energy from within.

It may be that we shall have to wait a few more years before we learn in what way the cooler air promotes greater energy and if it actually promotes a greater generation of heat within, but it does seem true that when we are in a cooler atmosphere, our appetites develop, indicating that something within is being used up more rapidly than when we are in an atmosphere of higher temperature. One might compare this with a fire which needs very little fuel when it is burning sluggishly. However, as soon as more draft is applied and the fire burns more rapidly, then fuel must be added at a greater rate.

It may be correct that some laboratory investigations did not throw any light on this very interesting point, but I do not think it is wise to say—without further investigation — that there is no truth in the theory. I realize the very great value of laboratory investigations, but I am one of those who feel we should be very careful in accepting as final anything concerning the reaction of a condition on the human body until it has been verified in the actual conditions under which it has to operate.

I have spent many years experimenting with different methods of heating, both in the laboratory and in the field, and have come to the conclusion that many laboratory tests should be taken as a guide only until the results have been substantiated in the home, office, school and other buildings. On the whole, the results obtained under normal conditions are more reliable than specially prepared laboratory tests. Laboratory tests are invaluable, and one may say essential, for obtaining some data; but when searching for information concerning the general reaction of any kind of heating on the human mind and body, we have to collect a lot of data spread over several years, and it appears to me that there is nothing like searching for this in the places where most of the ordinary people are found. During the years of my research work I invariably used the laboratory to obtain information which acted as a guide, but before actually accepting such findings, I had several systems installed and tests made on the job so that the results could be checked to verify or modify laboratory findings. Before we decided on the special floor construction for the Liverpool cathedral, which I believe is the largest heated floor in the world, I spent over a year experimenting with different types of flooring and the results of this kind of radiant heat on a large number of persons. It has been my experience that when people are selected for a laboratory test, they invariably let their minds dwell on the things which they think should happen, instead of relaxing and allowing the conditions to react on them as they would do in a normal way.

I am not surprised that some laboratory tests appear to give negative results, but I am surprised that negative results without substantiation are sometimes accepted as a basis for a theory which often proves to be an erroneous one, the result being that it is only after years of experience that the truth is eventually revealed. Isaac Watt, the great inventor, experimented with radiant heat over 150 years ago and gave up the idea because his results were negative. We now know that the only reason his results were negative was that he used polished surfaces instead of a dull rough surface; but we had to wait over 120 years for radiant heat to be introduced because a negative result was accepted as final. I am afraid that it is because many people are apt to accept laboratory tests as final that we still do not have a perfectly reliable system for health and comfort; and it is partly that reason why we get so much erroneous data and factors placed before us. I am sometimes astonished when reading articles which disclose how, from results of a few meager tests and isolated cases, assumptions of great moment are made and deductions formed.

While radiant heat may appear to be something new in this country and create some doubt in the minds of some engineers, I think it should be remembered that heating engineers in Europe have had over 30 years of experience with this kind of heating. While from this experience we know something of its advantages and reactions, we certainly would not suggest that radiant heat panels alone are the answers to all kinds of heating and air conditioning problems. I do, however, believe that more healthful and efficient systems are produced when, in designing a system, we pay more attention to the way heat escapes from the human body than simply to provide an apparatus which will raise the temperature of the air in a building to a predetermined degree—T. NAPIER ADLAM, chief engineer, Sarco Co., Inc.

Panel Heating, Fluorescent Lighting Feature New Addition to High School

ERWIN L. WEBER, CONSULTING ENGINEER, GIVES DATA ON INSTALLATION EMPLOYING PIPE COILS IN CEILINGS

SUMMARY—The third addition to the Clover Park high school, near Tacoma, combines panel heating and indirect fluorescent lighting. A total of 13,000 lineal feet of pipe coils are placed in the concrete ceiling slabs or embedded in suspended ceilings. The coils—of welded construction, bent on 6 in. centers—receive water from a converter furnished with steam from a central boiler plant. There are five separate heating zones, the water for each being supplied by a thermostatically controlled, three way valve which mixes hot water and cooler return water. . . . Flow and return mains are run in the attic space to avoid constructing trenches under the first floor (there is no basement). The ceilings are divided into 8 ft by 26 ft bays by 14 in. deep concrete beams. There is a lighting trough on each side of the beams; the coils are embedded between the beams

THE third addition to the Clover Park high school, near Tacoma, Wash., combines panel heating and indirect fluorescent lighting. The building comprises offices, locker rooms, music rooms and the foyer to the future auditorium on the first floor, and a large library and chemistry, physics, dietetics and biological laboratories on the second floor.

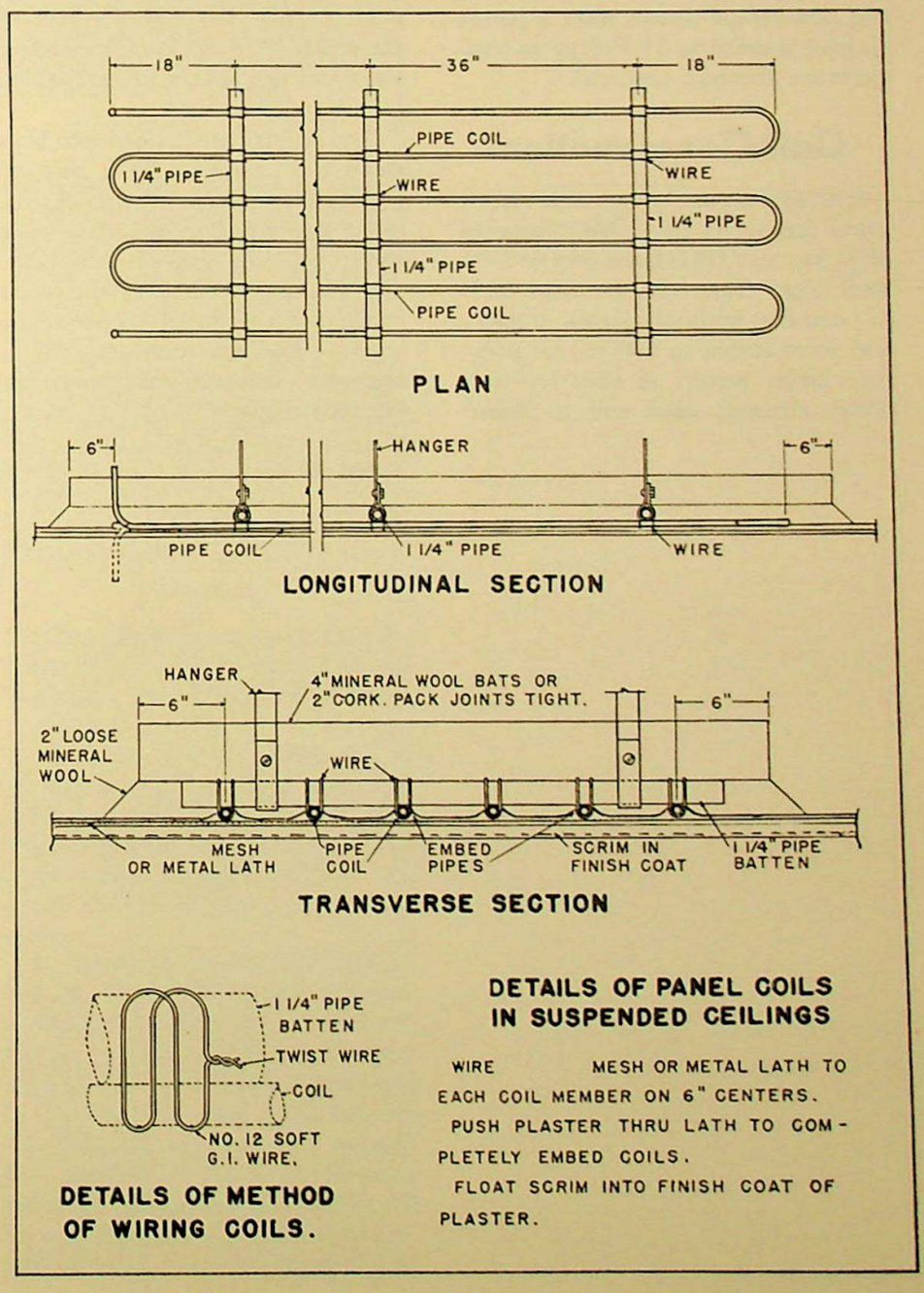
There is no basement. The first story has a concrete floor laid on the ground and is finished in rubber tile. The second story has concrete floor slabs and is finished in rubber tile and maple floors. The ceiling of the second story is a concrete slab, and there is a gable roof forming an attic space.

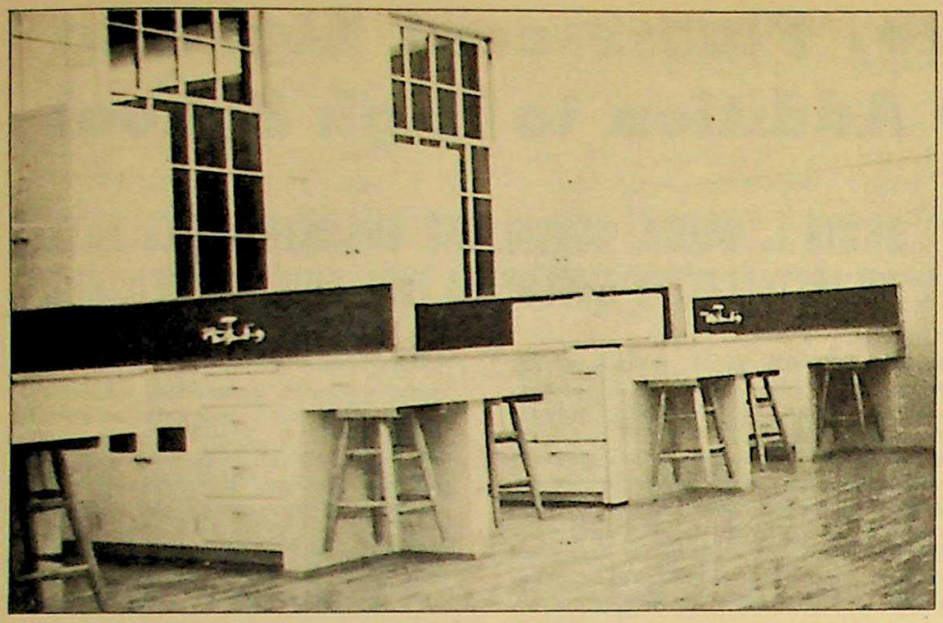
The water for the panel coils is heated in a converter with 40 sq ft of copper heating surface, by steam from the central boiler plant. The water is circulated by a centrifugal pump with a capacity of 140 gpm when operating against a head of 40 ft.

Five Zones

There are five separate heating zones—east rooms, west rooms, south rooms, library and music room. Each zone is supplied with flow water through a thermostatically controlled, three way, diaphragm mixing valve which derives hot water from the converter and mixes it with the cooler return water to supply each zone with water of the temperature demanded by its respective thermostat.

To avoid constructing underground trenches under the first floor, the flow and return mains are both run in the attic space. Branches from the flow main drop down to the flow valves in each room and supply the lines to the heating coils. Each coil is connected through an equalizing non-reflux elbow to the return main in the attic. This main pitches upward to the expansion tank to relieve air from the coils. The air is also relieved from other high points in the mains by auto-





This view of the dietetics laboratory was taken at night with no illumination other than that provided by the indirect fluorescent lighting system. It serves to show that spaces under tables, desks, etc., are not cold when ceiling heating panels are used, for the radiant heat rays are diffused and reflected like light rays

matic air relief traps. The equalizing non-reflux elbows were adjusted to give a uniform 15 F drop in temperature through each coil.

Coil Construction

The system comprises about 6000 lineal feet of ½ in., 5200 lineal feet of ¾ in., and 1800 lineal feet of 1 in. steel pipe. The coils are bent on 6 in. centers with all joints welded, and were tested to 500 psi air pressure under water. A steel ball was blown through each coil to insure against "inside welds" and other obstructions. About 70 per cent of the coils are in the concrete ceiling slabs and the balance are embedded in suspended ceilings.

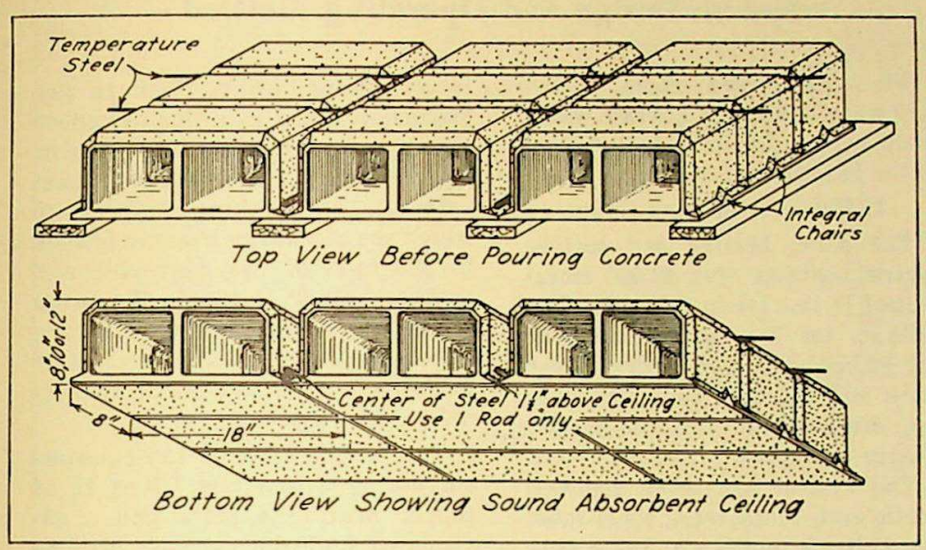
The ceilings are divided into bays about 8 ft wide and 26 ft long by 14 in. deep concrete beams. An indirect fluorescent lighting trough is placed on each side of each beam and the heating coils are embedded in the concrete panels between the beams. The acoustical material is applied to the side walls above the blackboard space.

The question is often asked if the space under tables, desks, etc., is cold when ceiling panel heating coils are used. The view of the dietetics laboratory answers that question when we note how clearly the stools under the tables are seen and remember that radiant heat follows the same laws as light, and that the light reflecting value of floors is less than 50 per cent while the heat reflecting value runs well over 80 per cent. Hence there is a much greater re-direction of heat rays than of light rays, resulting in a very noticeable uniformity of temperature. The photograph was taken at night, with illumination provided entirely by the indirect fluorescent lighting system.

The building was designed by Charles V. and Clarence Rueger, architects. The electrical, mechanical and sanitary equipment were designed by the author. The heating and plumbing were installed by the Advance Plumbing & Heating Co. The panel heating system was licensed from Richard Crittall & Co., Ltd., through Wolff & Munier, Inc.

Hollow Floors for Radiant Heating

F. E. Markus Gives Brief Description of New Type of Floor Construction Which Incorporates an Integral Duct System



SUMMARY—Research work by Markus & Nocka, Boston architects, on hospital construction has developed a new low cost, hollow fireproof floor system incorporating an economical method of circulating hot air through the floor for radiant heating. Applications to industrial and other building types appear equally feasible. . . . . The construction also lends itself for slabs on fill where radiant heating would be very desirable as, for example, in industrial buildings where high ceilings and large areas of glass are usually employed. Fire stations, airplane hangars and other buildings where large doors are wide open for prolonged periods are also logical possibilities for application of radiant heating

IN connection with research on hospital planning, where part of the problem consisted of developing a simple means of obtaining the advantages of radiant heat without high initial cost, a new type of fireproof floor construction (which is being patented) was developed which integrally incorporates a modular duct system. Certain features tend to bring the cost of this floor construction down to that of second class construction; namely, its lightness and consequent saving in reinforcing steel, self-spacing of units, self-spacing and aligning of reinforcing steel without the use of chairs, elimination of plaster ceiling, etc. There is reason to believe that considerable applications other than in hospitals may develop.

The construction also lends itself for slabs on fill where radiant heating would be very desirable as, for example, in industrial buildings where high ceilings and large areas of glass are usually employed. Fire stations, airplane hangars and other buildings where large doors are wide open for prolonged periods are also logical possibilities for radiant heating.

Strangely enough, in the first installation the choice of this floor system was made for reasons not originally contemplated; namely, a need for a light fireproof floor because of the limitation of existing foundations and the desire to conceal all sprinkler pipes. The sprinkler mains were run in the center of each structural bay at the neutral axis and at 90 deg to the floor ducts with one-head sprinkler runouts, right and left, concealed in the ducts. The light weight aggregate blocks are easily cut around pipes, access panels, etc.

In the use of the ducts for radiant heating there are several optional methods, depending upon conditions. All the available ducts may be used for hot air as is usually necessary in the case of the slab on fill, to keep the floor temperature low enough for comfort. Or in multi-story buildings where radiation is effected on both ceiling and floor every second or third duct can be used and the remaining voids left for use as pipe chases.

Main supply and return ducts for tying into the floor system are constructed in the usual manner and run at right angles to the floor ducts. In some cases the supply and return ducts can best be run in the furred corridor ceiling. In this arrangement the special outside end blocks become in effect 180 deg elbows. Another method is to place the supply duct only in the furred corridor ceiling, collecting all floor ducts into a return main at the outside wall, either furred on the ceiling below or inside the spandrel above.

DESIGNED · JUNE 1941.

Court House System Combines Panel Heating and Cooling, Conditioning

Erwin L. Weber, Consulting Engineer, Explains "Environment Conditioning" System Design and Operating Method

SUMMARY—Until wartime applications, problems, and restrictions took the center of the stage, panel or radiant heating and cooling were among the subjects given prime attention by engineers and contractors. Radiant heating—and cooling—are finding a number of interesting war uses, and the method is expected by many to enjoy increasing popularity in the tremendous peacetime construction to come . . . . Described here in some detail is an unusual installation combining panel heating and cooling and air conditioning, which serves the Yakima County, Wash., court house

THE YAKIMA County, Wash., court house has a complete "environment conditioning" system, comprising air washing, filtering, and tempering, and panel warming and cooling. In the design of the system, full advantage was taken of the peculiar climatic conditions prevailing in the region.

Yakima is in the rain shadow of two great mountain ranges, the Rocky mountains to the east and the Cascades to the west. It therefore has a semi-arid type of climate. The winter mean average minimum temperature is 20.8 F for January and the absolute minimum temperature is —24 F. The summers are hot and dry, with a mean average maximum temperature of 88.9 F for July and an absolute maximum temperature of 111 F. During the summer, the dew point temperature seldom exceeds 50 F. Well water at 55 to 56 F is available at a depth of about 250 ft.

The Boiler Plant

The central heating plant is in the basement of the jail section and comprises a hot water boiler with a stoker. Two future boilers are allowed for. Domestic hot water is generated in a 960 gal steel storage tank having a copper coil with 120 sq ft of heating surface, and is circulated through the building by a 1¼ in. by 1 in. motor driven pump. The circulating pump for the heating system has a capacity of 250 gpm against a static head of 30 ft and is direct connected to a 5 hp motor. The closed expansion tank is 36 in. by 96 in.; it is designed for 50 psi pressure.

Flow and return mains, a cold well water main, and a waste water main extend from the boiler room to the basement of the court house.

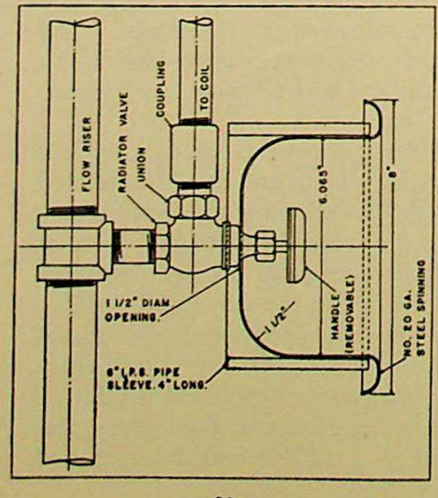
27,000 Feet of Pipe Coils

The panel heating and cooling system contains over 27,000 lineal feet of ½ in. pipe in 189 coils. The coils on the first and second floor are embedded in the concrete floor slabs and those on the third floor are installed in the suspended plaster ceiling.

The system has seven zones — north, east, south, west, court room No. 1, No. 2, and No. 3. The supply main for each zone is derived from a three way diaphragm mixing valve connected with the hot water from the converter and with the return water. These flow mains are on the basement ceiling. Branches from the risers have valves with special valve handle enclosures set in the outside walls and are connected to each coil or group of coils.

The return riser from each panel coil extends to the attic where it is connected through an equalizing non-reflux elbow *ENRE* to the return mains, which pitch to two expansion tanks in order to relieve all air automatically. The returns from the expansion tanks connect with the circulating pump, from which the discharge has one branch to the inlet of the converter and another branch to supply the seven mixing valves with unheated return water. The system was completely balanced by the use of an electro-differential thermometer.

Detail of valve handle enclosure used on the panel heating and cooling system. According to the specifications, the spinning should fit snugly into the pipe sleeve and should be finished with a gray filler priming coat. The pipe sleeve must be absolutely concentric with the axis of the valve stem



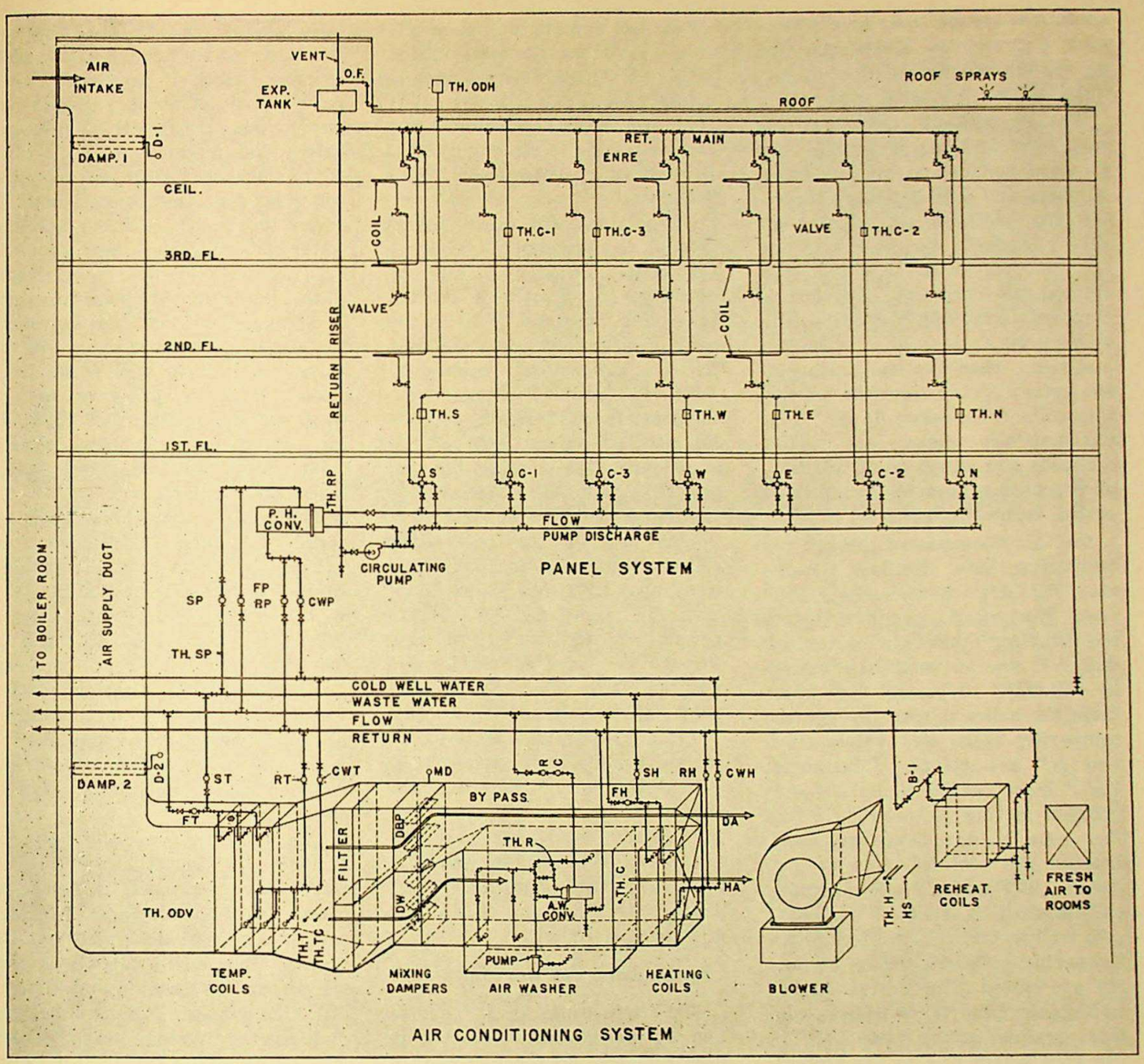
The converter is of the counter-current type and has 50 sq ft of copper heating surface and a capacity of 1,800,000 Btu per hr. The circulating pump has a capacity of 185 gpm against a head of 40 ft and is direct connected to a 5 hp motor.

There are only six radiators in the building. These are installed in the jury dormitories and are connected on the domestic hot water system to be used only for heating the dormitories at night after the panel heating system is shut down.

Ventilation and Air Conditioning

The ventilating and air conditioning system comprises an air washer of 20,000 cfm capacity, 9 ft long, with two sets of spray nozzles and one set of flooding nozzles; an air filter; three banks of tempering coils; and two additional two-bank reheating coils for heating and ventilating the basement. The blower is of the double width, double inlet type and has a capacity of 17,500 cfm at 1¼ in. water gage, geared with a v belt to a 7½ hp motor. In the penthouses are two exhaust fans, each with a capacity of 7500 cfm at ¾ in. water gage, connected by v belts to 3 hp motors.

Conditioned air is introduced into all rooms along the outside wall under windows, etc., and is discharged downward through diffusing registers. Vitiated air is exhausted over the doors to foul air ducts installed over the suspended corridor ceilings, from which it is discharged by the two exhaust fans.



This diagram of the panel system and the air conditioning system shows the various thermostats, dampers, valves, and other equipment for both winter and summer operation. The functions of the various parts are described in detail in the text. ("O.F." is the overflow from the expansion tank)

How System Operates

Water for the panel system is warmed or cooled in the panel heating converter (*P.H. CONV.* on drawing) and discharged to the flow main. The returns enter the circulating pump which feeds the converter and the pump discharge line in multiple. The flow water to the seven heating zones is derived through the seven three-way diaphragm mixing valves connected to the flow main and to the pump discharge main. Each mixing valve is controlled by a thermostat to mix flow and return water in the proper proportion as demanded by its respective thermostat.

Outdoor thermostat *TH.ODH* changes the system from heating to cooling operation. During the heating operation valves *FP* and *RP* are opened by thermostat *TH.ODH* to permit flow water from the boiler to pass through the shell of the converter, and valves *SP* and *CWP* are closed. Insertion thermostat *TH.RP* in the flow line from the converter is set at 130 F (maximum permissible temperature) and operates gradual acting diaphragm valve *FP*, which is reverse acting, to close automatically in case of failure of air pressure and thus avoid accidental overheating of the panel coils. During the cooling operation, valves *CWP* and *SP* are opened by thermostat *TH.ODH* to permit cold well water to pass through the shell of the converter, and valves *FP* and *RP* are closed. Insertion thermostat *TH.SP* in the waste water line operates valve *SP* and is set at 64 F, or other desired discharge temperature of the waste water.

Outdoor thermostat *TH.ODH* also automatically switches room thermostats *TH.S*, *TH.C-1*, *TH.C-3*, *TH.C-2*, *TH.W*, *TH.E*, and *TH.N* between summer and winter operation. These thermostats are all of the remote readjustable summer and winter type. This is necessitated by the requirement that the direction of flow of the water in

the panel system must be the same during summer or winter operation to relieve effectively the air upward to the expansion tank.

The outside air enters at the roof level and passes through the air supply duct and the two felted dampers *D-1* and *D-2*; these dampers are operated by solenoid air valves connected to the blower motor, to open when the motor is started and close when the motor is stopped. The fan motor is also stopped by an insertion thermostat and relay when the temperature of the return water from the tempering coils falls below 38 F. This automatically closes the intake dampers and serves as an additional precaution against the freezing of the tempering coils.

The air then passes through the tempering coils. Outdoor thermostat *TH.ODV* changes the system from heating to cooling. During the heating operation, valves *FT* and *RT* are automatically opened by *TH.ODV* to permit flow water from the boiler to pass through the tempering coils, and valves *CWT* and *ST* are closed. Thermostat *TH.T* is set at 50 F and controls gradual acting valve *FT* in the flow line to the tempering coils. During the cooling operation, valves *CWT* and *ST* are automatically opened by *TH.ODV* to permit cold well water to pass through the tempering coils and valves *FT* and *RT* are closed. Thermostat *TH.TC*, adjustable from 50 to 100 F, controls gradual acting valve *CWT* in the cold water line to the tempering coils.

From here the air may pass through the filter and bypass as dry air (*DA*), or it may pass under the filter and then the air washer as humidified air (*HA*), in varying proportions, depending upon the positioning of the interconnected dampers *DPB* and *DW*. These dampers are operated by the diaphragm valve *MD*, which is controlled by humidistat *HS*, or may be manually controlled from the system switchboard to maintain any desired humidity.

Air stream *HA* passes through the air washer, wherein the spray water is heated in the air washer converter (*A.W.CONV*) which is heated by the flow water from the boiler, controlled by thermostat *TH.C* operating gradual acting valve *C* set at 50 F (dew point control). Insertion thermostat *TH.R*, set at 78 F, operates the reverse acting valve *R* and acts as a safety valve to prevent overhumidification of the air if valve *C* becomes inoperative or in case the air pressure fails.

Air stream *HA* next passes through the heating coils. Outdoor thermostat *TH.ODV* adjusts the operation of the coils to heating or cooling operation. During the heating operation, valves *FH* and *RH* are automatically opened by *TH.ODV* to permit flow water from the boiler to pass through the heating coils, and valves *CWH* and *SH* are closed. One point of the two point thermostat *TH.H*, set at 70 F, controls gradual acting valve *FH* in the flow line to the heating coils. During the cooling operation, valves *CWH* and *SH* are automatically opened by *TH.ODV* to permit cold well water to pass through the coils, and valves *FH* and *RH* are closed. The second point of two point thermostat *TH.H*, adjustable from 50 to 100 F, controls gradual acting valve *CWH*.

Reheating coils *B-1* and *B-2* (not shown) are for the air conditioning system for the basement and are controlled by room thermostats in the basement operating gradual acting valves *B-1* and *B-2* in the flow lines to the coils.

Waste Water for Roof Spraying

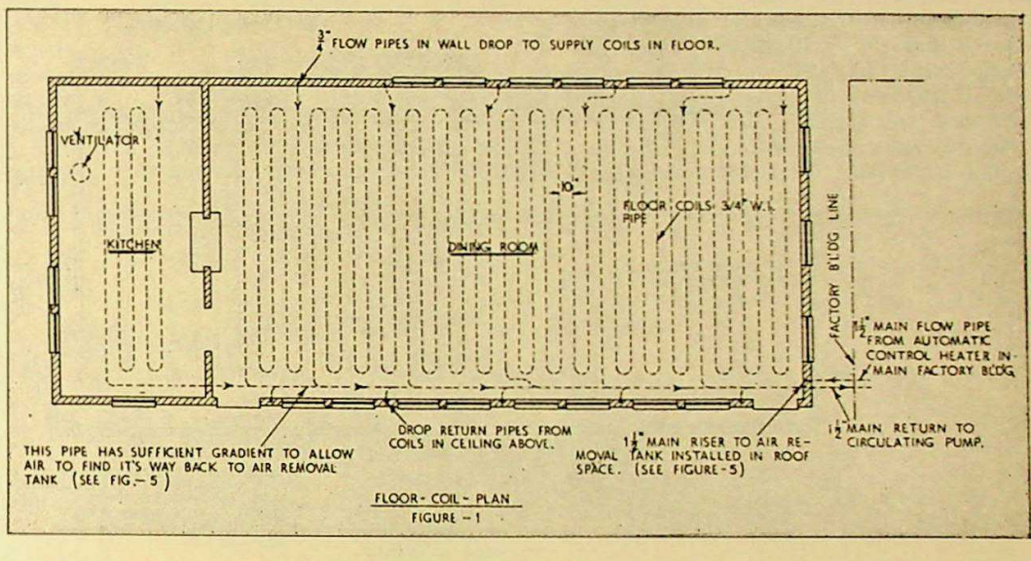
The waste water from the system during summer operation is used for spraying the roof for its evaporative cooling effect, and for lawn sprinklers. It also supplies the waste water header in the boiler room, which is provided with a relief valve set at 55 psi, and has two branches with diaphragm valves interconnected with two similar branches from the cold well water header. One branch supplies water to the boiler room and hot water tank and the other branch is used for flushing the water closets in the jail. Each of these two lines is arranged so that the valves in the waste water lines open and the valves in the cold well water lines close when the pressure in the waste water line rises to 50 psi, and vice versa when this pressure falls below 50, to utilize waste water whenever available.

The well contract has been let for a 12 in. and 10 in. cased well (12 in. as far as possible, reduced to 10 in. thereafter), 250 ft deep, with a pump having a capacity of 850 gpm against a head of 200 ft. The motor is of 60 hp capacity. Due to wartime restrictions the well installation has not been completed. However, city water at 65 F was used in limited quantities last summer with noticeable cooling effect.

The building was designed by Francis H. Fassett and H. Don Gouchenor, architects. The electrical, mechanical, and sanitary equipment was designed by the author. Ben Drinkwater was contractor for the heating and air conditioning system. The panel heating and cooling system was licensed from Richard Crittall & Co., Ltd., through Wolff & Munier, Inc.

Radiant Heating and Cooling for a New Plant Cafeteria

T. Napier Adlam Explains Installation of Floor and Ceiling Pipe Coils and Methods of Control


¾" FLOW PIPES IN WALL DROP TO SUPPLY COILS IN FLOOR.
VENTILATOR
KITCHEN
DINING ROOM
10"
FLOOR COILS ¾" W.I. PIPE
FACTORY BLDG. LINE
1¼" MAIN FLOW PIPE FROM AUTOMATIC CONTROL HEATER IN MAIN FACTORY BLDG.
1½" MAIN RETURN TO CIRCULATING PUMP.
DROP RETURN PIPES FROM COILS IN CEILING ABOVE.
1¼" MAIN RISER TO AIR REMOVAL TANK INSTALLED IN ROOF SPACE. (SEE FIGURE-5)
THIS PIPE HAS SUFFICIENT GRADIENT TO ALLOW AIR TO FIND IT'S WAY BACK TO AIR REMOVAL TANK (SEE FIG.-5)

FLOOR-COIL-PLAN
FIGURE-1

SUMMARY—**If you had to name one topic that invariably is brought up for a lot of discussion in any conversation about postwar developments and the future of heating and air conditioning, you'd probably say "radiant heating." We've run many articles on this subject, yet we can't seem to give HPAC's readers their fill. . . . Mr. Adlam, chief engineer of the Sarco Co., Inc., has had as much or more actual experience with such jobs as any other engineer; he describes here a radiant heating—and cooling—installation in a new industrial plant cafeteria, which has both floor and ceiling pipe coils. He explains in detail just how the coils were installed, and the functioning of the controls is carefully discussed.**

WHEN DESIGNING the radiant heat system for the new cafeteria in an industrial plant, the author had two or three objectives to take into consideration. The main object, of course, was to provide comfortable temperature conditions for the occupants in winter, but in addition to this, there was the hope that the installation would provide an adequate cooling effect in the summer. While the radiant panels are provided with these two principal ideas in mind, the equipment was also designed so that a series of extended tests can be made with various types of comfort controls. In other words, the building will eventually be used for research work in connection with radiant heating and radiant cooling.

The building is of frame construction with the sides covered with asbestos weatherboard on wood sheathing. The roof construction is slate with wood sheathing on rafters. Since the building is exposed on all four sides and has quite a lot of glass surface, the warming of the floor alone would not be sufficient to give adequate comfort conditions in extremely cold weather without making the temperature of the floor surface too high for "foot comfort." To provide sufficient heated surface to raise the mean radiant temperature of the room to the required degree, coils were placed in the ceiling of the main cafeteria but not in the kitchen.

Each Coil Has Flow Valve

Fig. 1 illustrates the outline of the coils inserted in the floor; these coils were constructed of ¾ in. wrought iron pipe spaced on 10 in. centers. All joints were welded. To insure an equal distribution of heat, the flow of water through each coil is permanently controlled by a flow valve, illustrated in Fig. 3A. In addition to the flow valve, an isolating lockshield valve was inserted in case it is desired to shut off any coil independently.

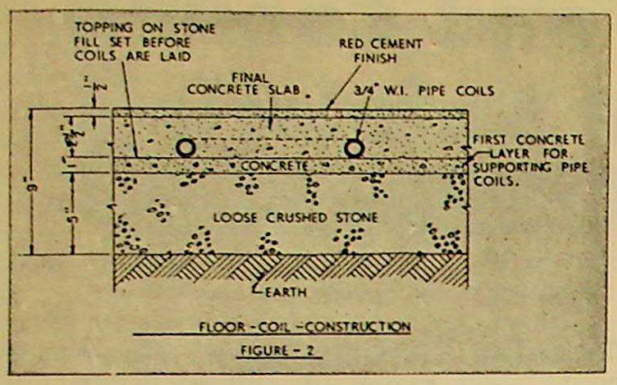
How Floor Coils Were Installed

Fig. 2 gives a part section of the floor construction showing how the coils were embedded in the concrete above the loose crushed stone. The loose crushed stone was first laid on the earth and then a layer of concrete 1 in. thick was finished off with a level surface. The coils were then placed in position and all connected pipes and mains welded.

The coils and mains were carefully graded to allow air to escape back to the air removal tank, and a hydraulic test was then put on the system to see that all joints were perfectly tight. The test given was a pressure test of 300 psi for 12 hr. After everything had been proved satisfactory, a layer of concrete 2½ in. thick was placed on top of the coils and connecting pipes and allowed to set. The floor surface of the cafeteria was finished with a top layer of red cement ½ in. thick and the floor surface in the kitchen was finished with linoleum.

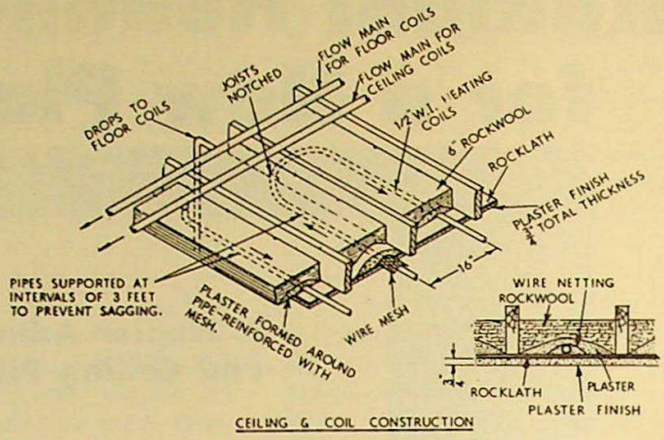
Ceiling Coil Installation

Fig. 3 gives an outline of the pipe coils installed in the ceiling of the cafeteria. These coils were constructed with ½ in. wrought iron pipe spaced 16 in. apart so that one pipe is placed in the center of each



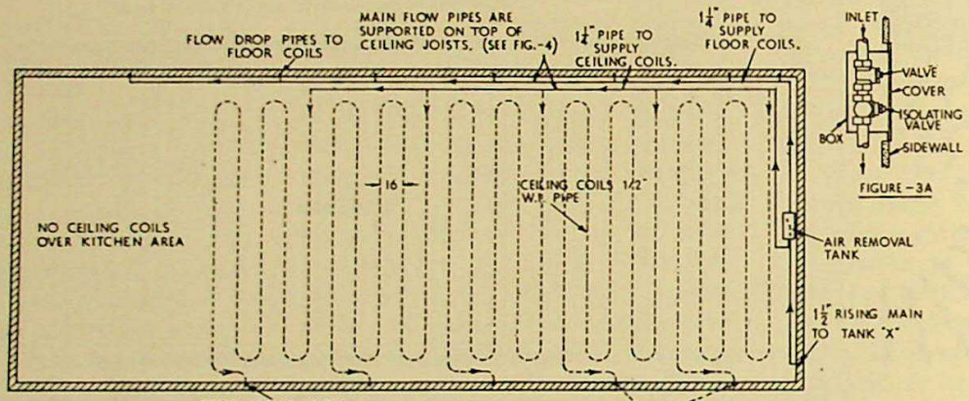
FLOOR-COIL-CONSTRUCTION

FIGURE - 2



CEILING & COIL CONSTRUCTION

FIGURE - 4


FLOW DROP PIPES TO FLOOR COILS
MAIN FLOW PIPES ARE SUPPORTED ON TOP OF CEILING JOISTS. (SEE FIG.-4)
1 1/2" PIPE TO SUPPLY CEILING COILS.
1 1/4" PIPE TO SUPPLY FLOOR COILS.
16"
CEILING COILS 1/2" W.I. PIPE
NO CEILING COILS OVER KITCHEN AREA
AIR REMOVAL TANK
1 1/2" RISING MAIN TO TANK "X"
DROP RETURN PIPES IN WALL TO MAIN RETURN IN FLOOR.
THE RETURN PIPE FROM EACH CEILING COIL IS EQUIPPED WITH A PERMANENT FLOW CHECK AND ISOLATING VALVE. (SEE FIG.-3A) THESE ARE LOCATED IN THE SIDEWALLS, WITH COVER PLATE.

CEILING-COIL-PLAN

FIGURE - 3

FIGURE - 3A

joist, as illustrated in Fig. 4. The ceiling was constructed with rocklath on joists and a total plaster finish ¾ in. thick. The ceiling coils were supported at intervals along their length to prevent sagging. The coils were carefully leveled and tested before adding the rocklath. After the rocklath was installed and the ceiling plaster added, the coils were then covered on top with plaster which extends the full distance between the joists. The plaster was reinforced with wire mesh to prevent crumbling and to help conduct the heat.

The purpose of the plaster around the pipes is to transmit the heat over the whole of the ceiling surface to give a more even temperature. After the plaster around the pipes was set, the spaces between the joists were filled with rockwool to a thickness of 6 in. The flow pipes supported on the joists and all other pipes and fittings in the roof space are well protected with insulating material.

Air Removal Tank

Fig. 5 illustrates the air removal tank and automatic air eliminator which are in the roof space above the cafeteria. The purpose of this tank is to insure that all air is eliminated from the water before the water passes into the smaller pipes of the heating coils. As the water rising in the pipe *X* flows into the tank, any entrained air will be separated and rise to the top of the tank where it will be released through the automatic air eliminator. Without the tank it would be possible for air to be carried through to the coils; this would greatly retard the efficiency.

Ceiling Coils Only Used for Cooling

The principal reason for having two flow connections from the tank is to enable the ceiling coils to be operated with cooling water in the summer. At the same time the floor coils can be isolated by closing valve *A*. When radiant surfaces are being used for cooling effect during hot weather, it is very unwise to cool the floor because a cool floor will create an uncomfortable condition and many of the occupants will suffer from cold feet even though the ambient air temperature may be fairly high. The rapid conduction of heat from the feet to the cold floor not only creates the discomfort of cold feet; it has also been found to bring about rheumatic pains and other ill effects. The only safe way to produce a cooling effect by radiant heat methods is to cool the ceiling or the side walls. Hence, the reason the ceiling only in this building is to be used as a cooling surface.

Method of Heating and Cooling

Fig. 6 illustrates the equipment used for both heating and cooling the circulating water and also the present method adopted to control their temperatures. An open top supply and expansion tank is installed at a sufficiently high level to keep the system full of water. This tank is fitted with a float controlled valve to maintain just enough water in the tank to completely fill the system when cold. Sufficient space is allowed above the controlled level of the water to take care of the expansion of the water as the temperature is raised.

The principal reason for having an open tank system is to enable a non-freezing solution to be used. In normal times the cafeteria and the factory may be left without heat over weekends and there will be danger due to frost. It also may be found desirable to use a refrigerant for circulating a cold liquid for cooling in summer.

A standard type circulator is used to force the water through the system and a standard indirect steam

heater is used to raise the water to a predetermined temperature which is controlled by the thermostat *T*. The temperature of the water leaving the indirect heater *H* is maintained at approximately 125 F and this mixed with a portion of the return water from the coils in the blender insures the correct temperature of the water entering the ceiling and floor coils. The blender valve *B* is controlled by the outside thermostat *S* with a final adjustment effected by the room thermostat *R* acting through the auxiliary bulb *F*, as indicated in Figs. 5 and 6.

The actual functions of the individual units of the heating and control system are as follows:

Steam, supplied from the factory heating system at a pressure of 3 to 5 psi, passes through the thermostatically controlled regulator valve *V* and heats the water in the indirect heater *H* to a temperature of 125 F. This temperature is controlled by a throttling type thermostat *T*, the bulb of which is inserted in the flow pipe from the heater. The circulator *G* circulates the water from the coils in the floor and in the ceiling and forces a portion of this through the indirect heater and a portion directly to the blender valve *B*, where a mixing of the water takes place. The temperature of the water leaving the blender through pipe *D* is controlled by the outside thermostat *S*. This thermostat is placed on the outside of the cafeteria where it is fully exposed to the surrounding air temperature and to radiant rays. In addition to the outside thermostat *S*, a room thermostat *R* is placed in the cafeteria which is subject to the dual effect of air temperature and mean radiant temperature of the walls, ceiling, glass, etc.

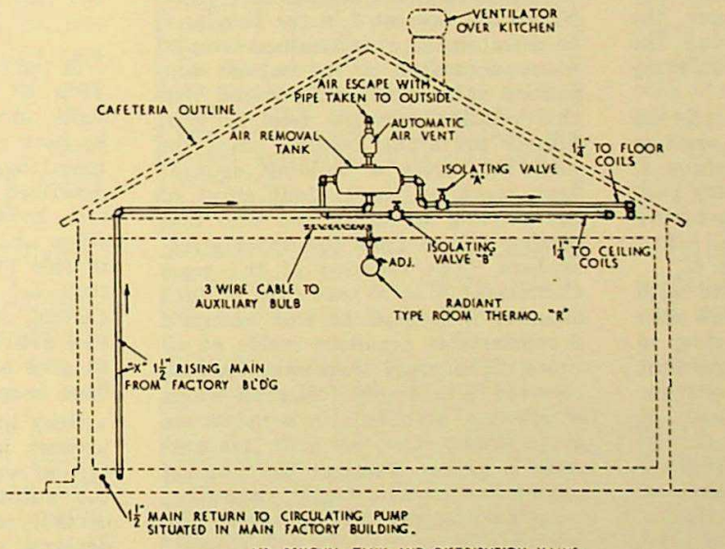
How Control Works

The function of the control is as follows (see Fig. 7):

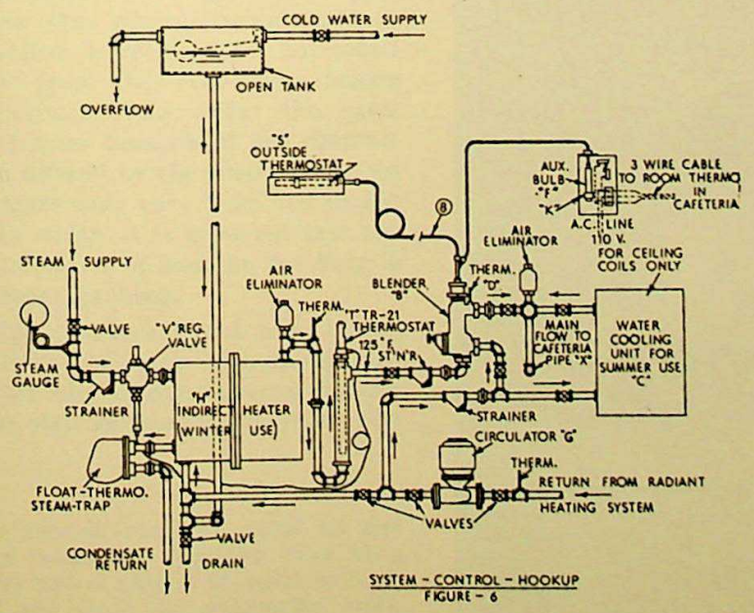
Hot water from the indirect heater enters the valve at connection *1* and a portion of the return water from the coils enters at connection *2*. The blended water leaves the valve at connection *Y*.

As the element *3* is heated by the hot water from the heater, the oil inside begins to expand and pushes the stem *4* outside, causing it to press against the lever *5*. The result of this action is to move the valve disc *6* off the top seat, allowing some return water direct from the pump to enter at connection *2* and mix with the hot water. The mixing takes place in the chamber at *7*.

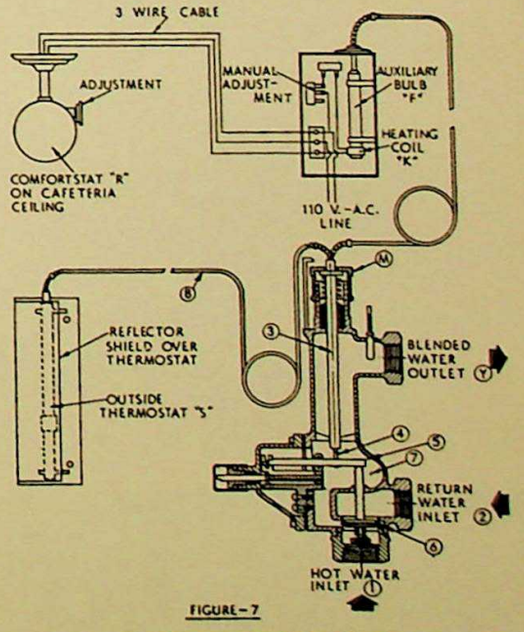
Since the element *3* is connected by the capillary tube *8* to the outside thermostat *S*, any increase in the temperature of the outside air will cause the enclosed oil to expand and force some of the oil from thermostat *S* along the capillary tubing *8* into the element *3*. The oil thus forced from the outside thermostat to the element *3* will increase the quantity of oil in the latter and cause the stem *4* to move outward. The valve disc *6*,


VENTILATOR OVER KITCHEN
AIR ESCAPE WITH PIPE TAKEN TO OUTSIDE
CAFETERIA OUTLINE
AUTOMATIC AIR VENT
AIR REMOVAL TANK
1¼" TO FLOOR COILS
ISOLATING VALVE "A"
ISOLATING VALVE "B"
ADJ.
1¼" TO CEILING COILS
3 WIRE CABLE TO AUXILIARY BULB
RADIANT TYPE ROOM THERMO. "R"
"X" 1½" RISING MAIN FROM FACTORY BLDG
1½" MAIN RETURN TO CIRCULATING PUMP SITUATED IN MAIN FACTORY BUILDING.

AIR REMOVAL TANK AND DISTRIBUTION MAINS
FIGURE—5



SYSTEM - CONTROL - HOOKUP
FIGURE - 6



FIGURE—7

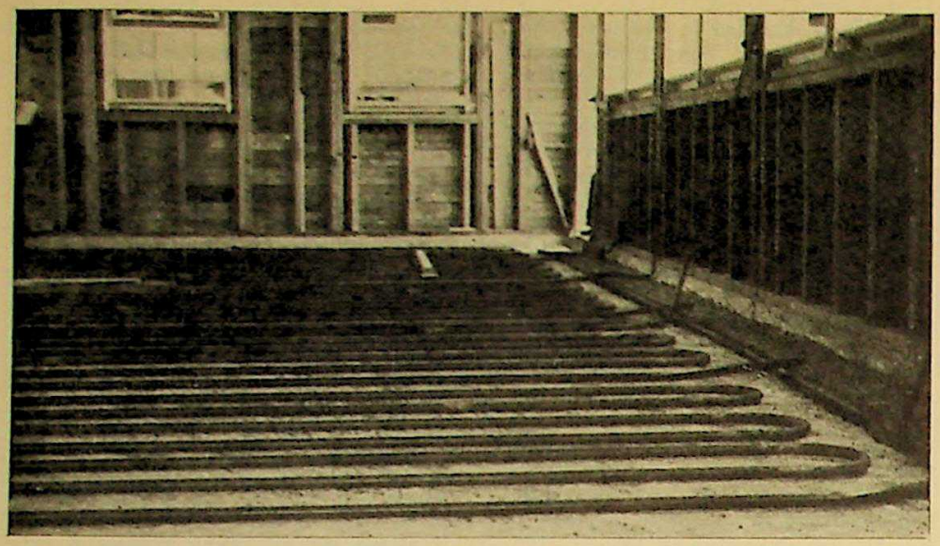


Fig. 8—Wrought iron pipe coils ready for concrete floor

therefore, takes up a position midway between the hot and return water ports, depending upon the temperature surrounding the outside thermostat *S*. Thus, a predetermined relation is maintained between the outside weather conditions and the temperature of the water circulating to the heating coils.

The thermostatic system of the control thus comprises the outside thermostat *S*, the capillary tubing *8*, the element *3*, and the auxiliary bulb *F*, and any change in temperature surrounding either of these will affect the position of the valve disc *6*.

The auxiliary bulb *F* is fitted with an electric heating coil *K* which may be heated more or less according to the function of the room thermostat *R*. Any increase in the temperature surrounding the auxiliary bulb *F* will cause the oil content to expand and force some of this into the thermostatic element *3* and the effect of this will be to move the valve disc *6* closer to the hot water port and thereby reduce the temperature of the water flowing to the radiant heat coils.

While it is possible by the combined action of the outside thermostat *S* and the element *3* in the blender *B* to maintain a predetermined temperature according to the outside conditions, it is occasionally found that this relation does not meet all conditions prevailing outside, since the heat loss from a building depends very much on the radiant effect of surrounding buildings and also that coming to and from the upper stratosphere. The function of the room thermostat *R* is to take care of such changes in conditions and maintain a comfortable condition inside at all times. The room thermostat is constructed with a spherical shell which is affected both by air temperature and radiant rays; more or less current is passed through the heating coil on the auxiliary bulb, depending upon the temperature effect on the sphere.

Adjustments can be made on the auxiliary bulb so that the room temperature can be raised or lowered to suit occupational requirements. The blender valve is also fitted with an adjustment so that by turning the knurled knob *M* the temperature of the water circulating in the coils may be raised or lowered.

Floor Temperatures

Since this system was installed, an outside temperature as low as minus 5 F has been experienced and the conditions have proved perfect. The surface temperature of the floor, even with such extreme weather conditions, never goes above 80 F. With more moderate outside temperatures the surface temperature is not perceptible to the touch.

For test purposes the temperature of the circulating water was raised to 160 F and allowed to operate at this temperature for several hours with no injury to the plaster or other material used in the construction of the building.

The Cooling System

A cooling unit is provided at *C* (Fig. 6) and the temperature of the liquid in the system will be controlled by both an outside thermostat and a room thermostat in the same way as described for the heating. This control, however, is in its experimental stage and, therefore, is not described in this article. Later, when the author has been able to develop this control, it will be the subject of a new article which we hope to be able to give after a number of tests we hope to make in the summer of 1943.

Very little has been done up to the present in controlling the temperature of water for radiant cooling, and the author is hoping to develop a control which will meet this great demand.

Floor Heating System in Hangar Conserves Metal

J. K. Fairbairn and John D. Dillon Describe Radiant Heat Method Using Nonmetallic Ducts Circulating Warm Air Heated by Steam

IN THE expansion program of a large naval base, the heating and ventilating design section of Giffels & Vallet, consulting engineers, was called upon to lay out (as occasion demanded) steam, vapor, vacuum, single or two pipe hot water, or warm air heating systems in order to suit the conditions of the innumerable types of buildings comprising the program. In general, picking the type of heat to suit the building was a very simple matter, since the construction in most cases was standard and the use of each building was conventional. The buildings which offered the most difficulty, from the heating man's viewpoint, were the hangars.

Difficulties in Heating Hangars

The conventional method of heating hangars is by means of vertical flow steam unit heaters hung in the trusses, or floor type unit heaters with recirculating ducts returning the air to the heater from the ceiling spaces. Both these systems of air circulation present certain disadvantages. The vertical flow sometimes fails to reach the floor when the hangar is crowded, since the wings present a very effective barrier. The horizontal flow from the floor type heater sometimes fails under the same conditions because of the obstruction offered by the fuselages. Since hangars may vary from 150 to 300 ft in width, it is apparent that the distribution of heat at the floor is a major problem.

The structural and use characteristics of such a building are such that the advantages of a warm floor slab are easily apparent. The necessary wide span requires a somewhat lofty roof, where heat is not needed, since the work is at the floor. The floor is unbroken by any obstructions, such as machinery or machinery foundations or any necessary services. There is one unbroken space in which there are no fixed positions of work, so that wide and uniform distribution is essential.

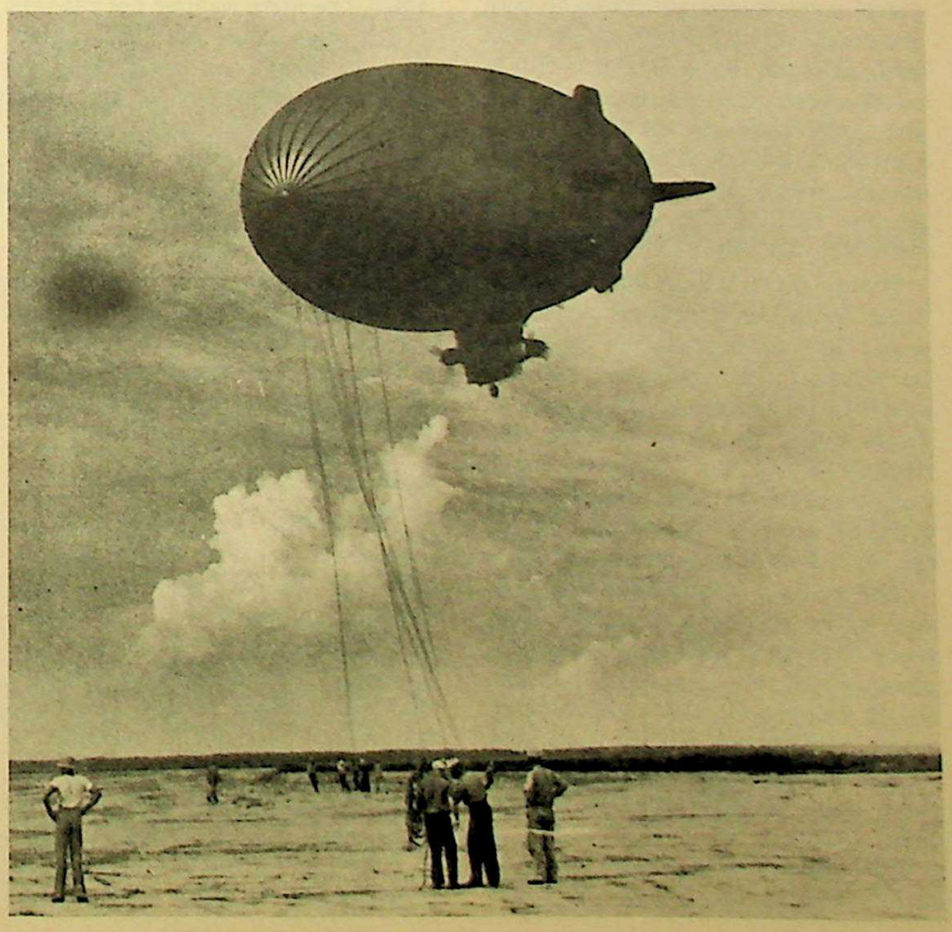
The problem of the doors is an ever-present headache, too. Opening a hangar door is just like tearing the side off the building, and many systems have been designed to offset or prevent the inrush of cold air. Most of these have been curtains of high velocity heated air which automatically blanket the opening when the doors are thrown back.

After considerable study of this particular project by the authors, and much consultation with the

Radiant Heating

There are many variations on the theme of radiant heating. Pipe coils in the floor, the ceiling, or in some cases the walls may be used to circulate steam or hot water. There are possibilities with electricity as the heating means. Warm air may be used to heat various types of ceiling or floor construction.

On the project described here—a hangar—warm air supplied from coils heated with low pressure steam is circulated through cement-asbestos piping or ducts in the floor construction in order to heat the floor slab. The authors discuss the thinking leading to the selection of this radiant heating system, and describe the savings in metal and other advantages achieved.



The ground crew at a naval air station seizes the handling lines of a Navy patrol airship to assist in landing the huge anti-submarine craft. (Official U. S. Navy photograph.)

structural department, it was decided that a radiant floor slab heating system would have many advantages. A very pleasing development occurred when a cost estimate showed that it was also lower in cost of installation as compared to the other methods considered. The naval authorities in charge of construction were most receptive to the idea of anything that would improve the job, and enthusiastic about anything that would lower the cost. When they saw both advantages presented to them in a single job, permission was immediately forthcoming to install a radiant heating system in a hangar.

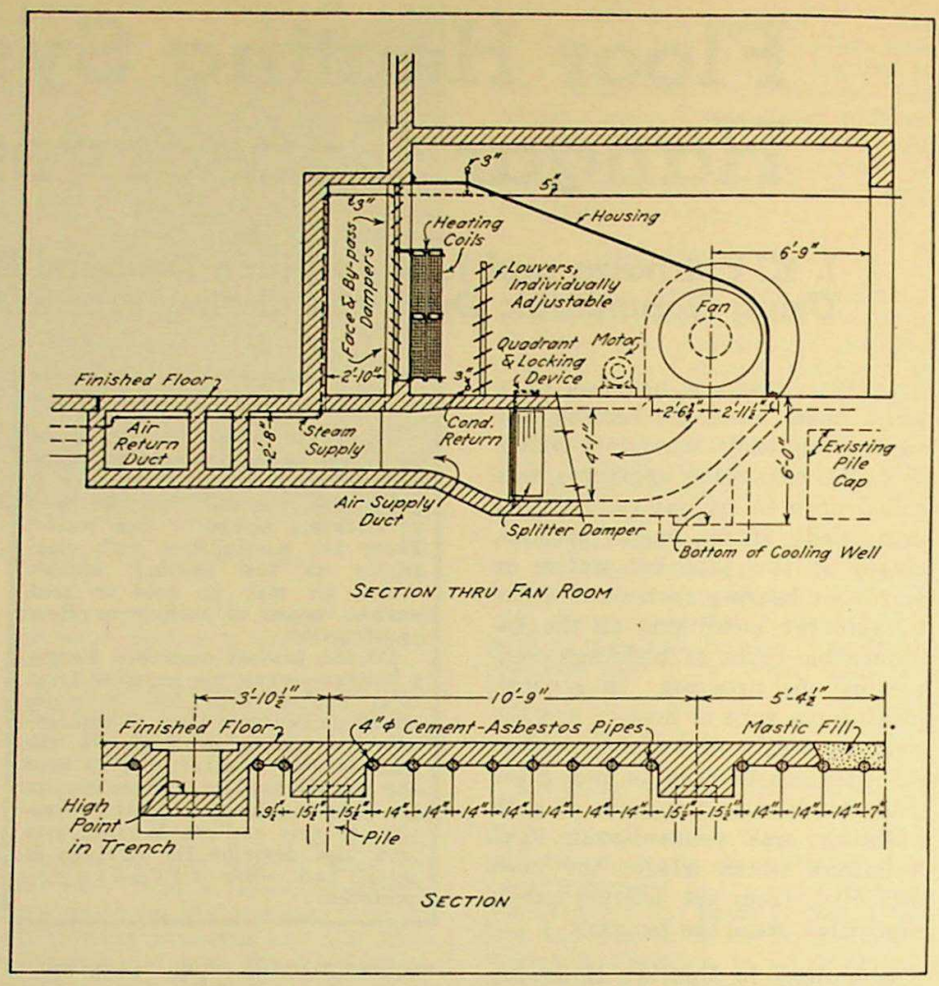
Design was started at once on a system of hot water coils in the floor, with the water heated by steam from a central plant. The hangar was to be built from a standard set of architectural and structural plans, and construction was going on while we were designing. The design was completed just about the time of publication of a list of restricted materials by the Army and Navy Munitions Board. We found, on checking the job for materials used, that the radiant job would use about 8 tons more metal than a unit heater job for the same hangar. Even though the cost of the radiant job was estimated to be about two-thirds of the cost of the unit heater job, the latter was selected for installation on the basis of the weight of metal saved.

Radiant Heating Using Warm Air

Since the authors had successfully installed a radiant floor job using air as the heating medium, permission was requested and secured to redesign, using a system of ducts under the floor. Before this design could be completed, the construction of the hangar was finished and the floor was poured, the unit heater job being installed.

The radiant heating design work was by no means wasted, however, since the data gathered were applicable to any standard hangar. As it happened, the next hangar was not standard, but we were able to use our material to great advantage, and to shorten the design time.

The subject hangar is approximately 400 ft long by 220 ft wide, with leanto structures 35 ft wide absorbing part of the space on each side. The main hangar floor is thus 150 ft wide. The original intention was to heat the entire job by radiant means, but it developed that the leanto sections would have considerable machinery, and we had no information as to its location. It was therefore decided to heat only the hangar floor with the radiant system, and to take care of the leanto wings by means of convection heating. This decision eliminated the necessity of adjusting the duct system to accommodate machinery foundations.



Duct System Under the Floor

The system as finally developed consists of concrete supply and return air trenches on each side of the hangar proper, with the underfloor duct system between the trenches. The supply trenches furnish air through vertical ducts and registers to the leanto sections as well as to the floor system. The returns are collected from the leanto through registers near the floor in the exterior walls, and taken by concrete trench to the main return trench for the hangar floor. Both returns are taken overhead through wooden duct to the fan room.

The underfloor duct system required much study. Tile, concrete, and fiber ducts were considered, priced, and installation costs estimated. Tile and concrete were ideal from the standpoint of heat transmission, but in the 4 in. size these were available only in 1 ft and 2 ft lengths. The expense of wrapping the almost innumerable joints to prevent seepage of concrete, as well as the difficulty of keeping the tile lined up during the pouring of the floor, caused us to look further for our duct work. Fiber was rejected because of expense and resistance to heat transmission. We finally settled on a cement-asbestos pipe which was available in a standard length of 10 ft, and which was supplied with a coupling of the same material. This pipe has a heat transmission factor one-quarter as high as concrete, which made its ¼ in. walls equal in resistivity to 1 in. of concrete. This resulted in a slightly larger temperature drop from the air to the surface of the floor, which was

compensated by raising slightly the air temperature under the floor.

The width of the hangar floor meant that the run of duct would be long, and that the temperature drop along the run would be high. The indicated high temperature drop suggested return bends under the floor, in order to equalize temperatures across the floor. This meant, however, an approximate doubling of the run, and in the 4 in. duct the friction rapidly mounted to a forbidding figure. Moreover, the drop in temperature would increase with the added length of run, and the large drop would force us into an initial temperature too high for comfort.

Heater Rooms and Fans

Two heater rooms were installed, one on each side of the hangar. The air heated on one side is blown under the floor through a multiplicity of ducts, and collected on the other side in a return duct, which is reversed to equalize the friction. This return duct is carried to the suction side of the fan in the second heater room. Here the air is reheated, and blown back under the floor through a second multiplicity of 4 in. ducts which alternate with the first. Thus the flow of air in adjacent ducts is in opposite directions, and the warm end of one duct is adjacent to the cool end of the next duct. This design accomplishes the necessary equalization of temperatures across the floor, holds the initial temperature down, and keeps the fans to a reasonable size. In another type of floor the runs could be shortened to achieve better results, but this particular design was limited by the wheel loads of the large planes. Distribution duct work under the floor would have been costly in construction, would have used more steel, and would probably have delayed construction, which could not be permitted.

There are several factors affecting the heat distribution with the radiant heating system, which were calculated only on arithmetical averages. One of these is the heat diffusion to be expected from the earth under the floor slab. Another is the distributing effect of the reinforcing steel which is set in the slab above the ducts. Since the position of the steel will vary with respect to the ducts, considerable variance is expected in the heat diffusion caused by the reinforcing. No attempt was made to limit the leakage of heat into the ground outside the building. The amount lost at the ends is negligible, and at the sides of the hangar floor the loss is desirable, since it heats the floors of the leanto wings and materially raises the mean radiant temperature.

Heating the Leanto Wings

The design of the heating system for the leanto wings differs very little from any ordinary warm air heating system, except that no metal ducts were used. The outlets were spaced at regular intervals along the interior wall where no offices were located. The returns were similarly spaced along the outside wall to give reasonable distribution of the air. The returns were placed at the floor, and gathered into one concrete trench, which spills into the main return to the fan.

Several large trucking doors in one leanto needed compensation for infiltration when opened. This was done by means of increasing the duct discharge at these locations, and controlling the discharge by thermostatically controlled dampers in the ducts. When the doors close, the dampers modulate somewhat to maintain an even temperature. When the doors open, the dampers open completely at the inrush of cold air and attempt to blanket the opening. All other openings in this and the other leanto are equipped only with manually operated supply registers.

Steam Is the Source of Heat

The source of heat is low pressure steam taken from the underground distribution system and piped to the heating coils in each heating unit. There are three rows of coils, each equipped with an automatic steam valve.

The control of the system is simple and effective. The flow of steam to the coils is controlled by the temperature difference between the air entering the heating unit, and the air leaving. This differential is raised or lowered in step with the outside temperature. Humidity is added for the benefit of the leanto wings. Each heating unit is separately controlled, and the leanto sections are thus zoned. The large drop in air temperature through the floor prevents one control from interfering with the other.

Advantages of the Heating Design

Under the design requirements the job seems to satisfy every need. The use of metal was reduced to a minimum, since the steam is piped to two places only, and all duct work is nonmetallic. The number of fans and motors was reduced to a minimum, with a definite saving in horsepower. No copper or other nonferrous metals are used except in the electric motors and controls, and in the fan bearings.

The heat loss calculations of the building showed that we had sufficient floor area to allow us to reduce the interior air temperature, which should result in a saving of steam. The heat is well distributed, and placed where needed; and unless the doors are allowed to remain open for long periods, the door problem is solved by the large residual heat and immediate recovery from the slab radiation.

A cost breakdown showed the cost per square foot of floor space (which is, after all, what the owner is paying for) to be $0.244. The extra cost of trenches in the floor, and all other such costs for work done by the building trades applicable to the heating plant, is included in this figure. The weight of metal used in the heating system is about 10,000 lb.

What 500 Installations Have Revealed About Radiant Heating

Charles A. Hawk, Jr., of the engineering service department of the A. M. Byers Co., has analyzed some 500 installations of radiant heating and studied many of them in the field. From this great amount of information, he has summarized the practical pointers given here on pipe coil layout, floor construction, insulating against downward heat flow, venting and draining pipe coils, temperature control, etc. Thus, his role is that of a reporter presenting the actual practice of a variety of engineers and contractors. The wide interest in radiant heating as an established wartime, and a promising postwar, method—and in the type of information given by Mr. Hawk—is demonstrated by the enthusiasm with which he has been received when speaking on the subject recently before engineering gatherings in a number of cities

IN ORDER that we may proceed from a common starting point, suppose we begin with an accurate understanding of exactly what radiant heating is. Reams and reams have been written to describe radiant heating, but in the final analysis it is nothing more than a system of producing comfort conditions by means of large, warm, room surface areas instead of depending on the movement of relatively high temperature air currents.

In a radiant heating system the temperatures of the cold room surfaces—such as outside walls, ceilings, etc.—are raised—either directly or by re-radiation—and thus the body's radiant heat loss is held at a comfortable level. The importance of this method of approach to the comfort problem is obvious when you consider that the major portion of the heat dissipated from the body is in the form of radiation loss—something in the neighborhood of 50 to 60 per cent of the total heat given off. This simply means that once an accurate control is established over the radiating factor, the comfort problem is near to being solved.

This basic fact is absolutely necessary to an understanding of the principles of radiant heating and is the major reason for the tremendous enthusiasm of those people who live or work in a radiant heated space. You see, these people become used to conditions in which the heating system behaves much the same as the re-radiation of electric lights. It produces a sensation of gentle warmth such as that experienced on a bright spring day—there is no sensation of stuffiness, "cooked" air, or drafts.

Coils May Be in Floor, Walls, or Ceiling

Experience seems to indicate that the simplest and easiest method of accomplishing this is to place pipe coils or grids in the floor and pass hot water through the pipes. The pipe runs may, of course, be placed in the walls or ceilings but we have come to feel that the floor type system is the first choice with the ceiling coil in the position of second choice and wall coils only in a supplementary capacity to either of these. For this reason, I shall confine my comments to the floor type system.

In a structural sense the floor type radiant heating system is exactly the same as the conventional forced hot water system except that pipe coils are substituted for radiators. The same boilers, expansion tanks, circulators, etc., are used, and you may safely consider the integration of these elements to be exactly the same for the radiant heating system as for the conventional hot water system.

Calculating Radiant Systems

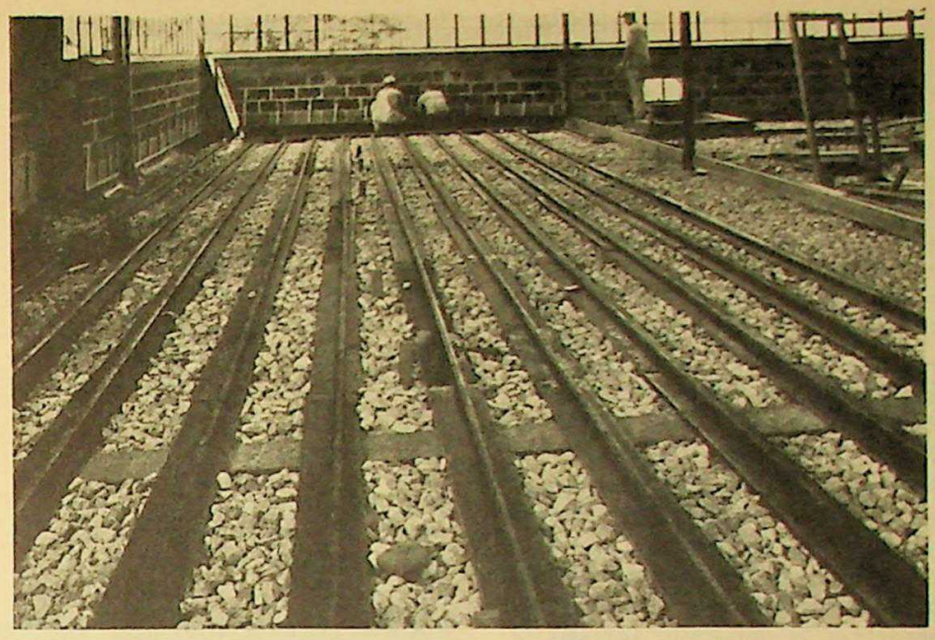
The matter of calculation for a radiant heating system is not as intricate as you might believe. The principles are firmly established and begin, naturally, with an accurate calculation of heat loss from the space under consideration. The Heating, Ventilating and Air Conditioning Guide, published by the American Society of Heating and Ventilating Engineers, covers this type of calculation very thoroughly. The difference in calculation for a conventional system and a radiant system occurs when you begin the calculation of heat input to balance this loss and here's the fundamental trick: For a conventional system you're used to thinking of output from equipment such as radiators only in terms of losses to air at a given temperature. In a radiant system, two kinds of losses or output from the warmed surfaces are considered—the losses by radiation to the cooler room surfaces and the loss by convection to the air.

Floor Construction

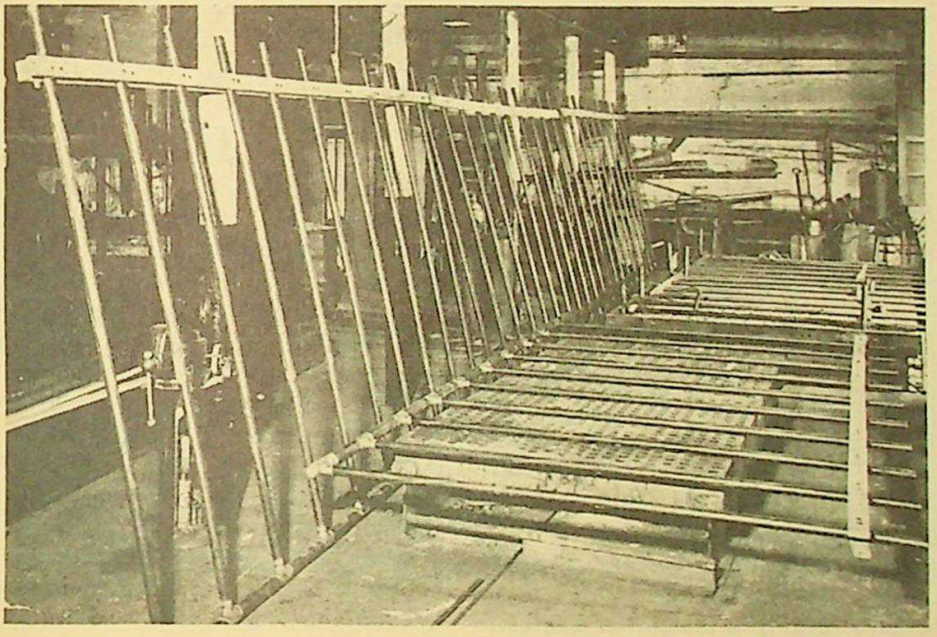
After calculations have determined the physical characteristics of any particular radiant heating system, the next problem is to integrate the pipe coils or grids into the structure being planned. Most of the radiant systems which have been used in this country have incorporated heating coils in concrete slabs which may or may not be on the ground. The thickness of the slab is of no great consequence since there is ample evidence to prove that the system works equally well with slabs ranging from 3 to 8 in. or 10 in. The pipe coils may be either encased within the concrete, in contact with the lower surface, or several inches below, embedded in gravel or crushed stone.

At this point I should like to drop a word of warning about slab

Grid type coils supply the heat for a plant addition near Baltimore; both the supply and return manifolds for these pipe grids were shop fabricated



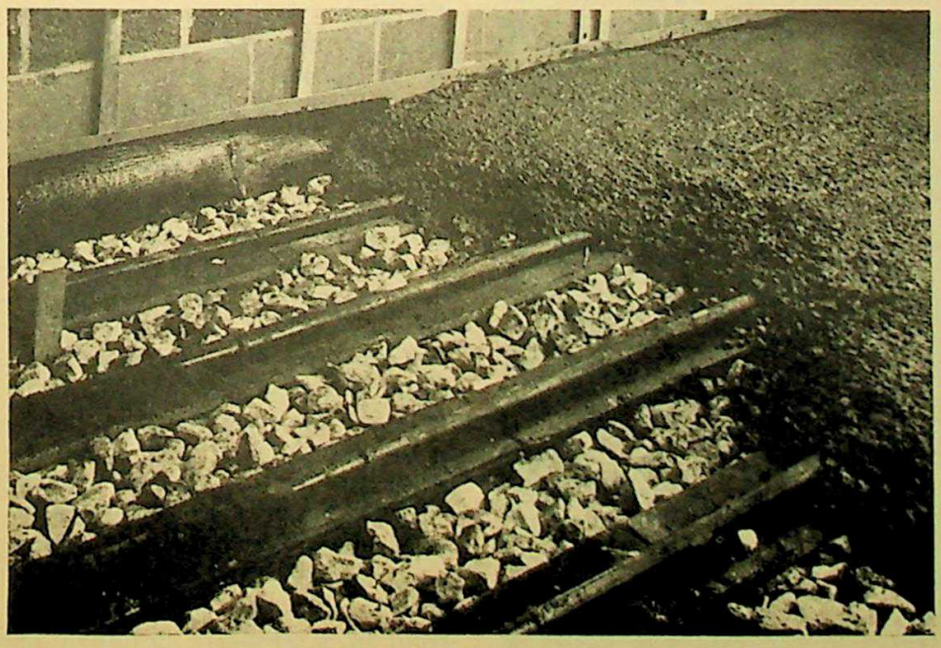
The manifold sections were moved as units to the site and integrated into complete grids on the site of the job

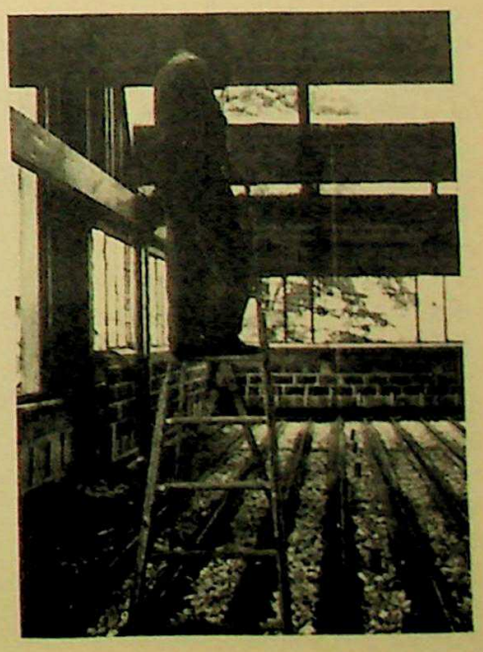


BOTTOM LEFT

The grids in place over the crushed stone base. The strips under the individual pipes are 1 in. insulating board. At this point the entire system was tested under 400 psi pressure for 2 hours; no leaks developed

In order to mark the location of the pipes so that the machinery could be anchored to the concrete without danger of damaging them, bench marks were placed on the joist directly above





construction in connection with ground moisture. Concrete is a relatively porous material which will absorb a considerable amount of water coming from either surface sources or rock formations. For this reason it is important that suitable precautions be taken to insure a dry floor. In any case, it is our recommendation that a 6 or 8 in. course of gravel or crushed stone be placed under the slab, with a waterproofing seal included between the two elements in locations where there is any reason to suspect the presence of appreciable water. Of course, good drainage practice such as would normally be followed under and around the foundation of any structure is definitely advised.

There have also been a great many installations made involving wood floor construction. Usual practice has been to lay the flooring directly over the coils, nailing the flooring either to sleepers or to joists notched to receive the pipes. The air space thus enclosed should be effectively blocked off so as to prevent the movement and consequent loss of heated air.

Sinuous Coil or Grid?

The actual pipe runs usually take the form of sinuous coils, or grids in which a supply manifold concurrently feeds a number of runs which feed into a return manifold. Both types have their individual merits. The sinuous coils are usually less expensive to fabricate and a little easier to design. However, the frictional head developed usually climbs so rapidly with increases in the total length that the range of practical working pressures limits this type of coil to either small structures or small areas of large structures. The grid type coil, although normally requiring a few more welds, embodies better hydraulic and thermal distribution characteristics. The vagaries of individual designs prevent making any broad statements as to the relative merits of the two coils, but it would be safe to say that the grid type coil is generally adaptable to large structures and the sinuous coil to small ones.

Insulating Against Downward Heat Flow

The question of insulation against downward heat flow from pipe coils placed on or near the ground is not as serious as many people believe. It is not quite possible to determine the exact amount of this loss, but some general calculations can be made. These indicate that approximately 30 per cent of the total heat input will be dissipated to the ground in uninsulated installations while a figure of 20 per cent is fairly accurate for cases in which insulation is used. This may seem a little high at first glance but the percentages are based on a total heat loss for the room or structure which does not include any heat losses downward. Consideration of this factor would greatly reduce the percentages just mentioned and provide a much more favorable comparison with downward losses from the conventionally heated structure. Furthermore, experience tends to indicate that these assumed rates of downward heat loss are very generous and that in actual practice they are much less than the figures I have given you. At any rate, we recommend continuing their use until additional research makes more accurate calculations possible. Considering this experience, the designer's question of whether to use insulation under the pipes becomes largely a matter of achieving results in keeping with the economic characteristics of the structure.

Venting and Draining the Pipe Coils

The matter of venting the pipe coils of a radiant heating system seems to be one of personal opinion. Actual installations are about divided between those which incorporate air vents from the pipes and those systems which are vented only at the expansion tank. A great many authorities insist that vents be provided; while just as many equally good authorities contend that a low velocity, low temperature, forced system does not require venting at any point except the expansion tank. So far, we have heard of only one installation made without vents which seemed to suffer to any degree as a result. This particular installation embodied coils on four different levels—a single closed system in which the highest coil was farthest from the boiler. Apparently an air lock developed because circulation in this highest coil was resumed as soon as a vent was tapped into the high spot.

Present practice seems about evenly divided between systems which can be completely gravity-drained and those which can be only partially drained or not at all. Where positive drainage was desired, a suitable tap has been included at the low point in the system and all lines pitched about ¼ in. in 10 ft. In slab-type structures, a small, drained pit is cast around the tap, when pouring the slab, and covered with a suitable traffic plate. However, where functional studies have indicated that drainage was seldom needed, practice has been to simply install a tap and count on using compressed air to blow the lines clear if it were ever desired to drain the system.

As to the selection of the circulator, this type of equipment is so well-known and highly developed that the only comment I feel constrained to make is that care should be taken to choose a pump of sufficient capacity rather than resort to the fairly common practice of shaving a few dollars by the use of an undersized pump. Certainly the installation of a pump of the right size would seem to be absolutely necessary in a well-engineered installation.

Does Floor Get Too Hot?

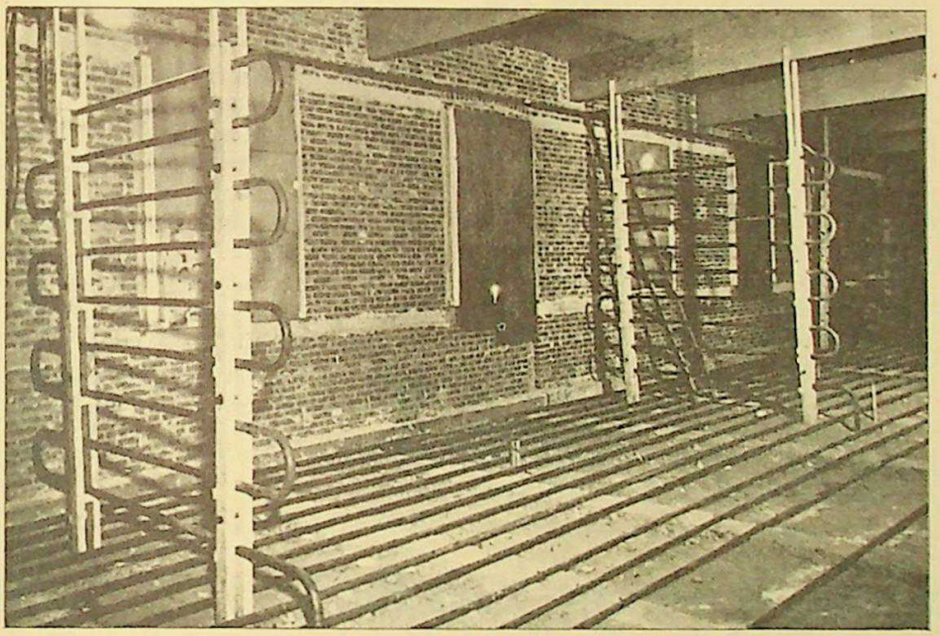
Among the questions most often asked about floor type systems are "Doesn't the floor get too hot?" and "Will it work with wood floors or rugs?" The answer to the first question is that a properly designed system will never produce floor surface temperatures above 85 F and this temperature—based on the experience of hundreds of installations—is not excessive. As a matter of fact, it is almost impossible to tell where the heat is coming from in a properly designed in-

stallation even though floor temperatures do reach 85 F. This surface temperature question also bears a relation to the question of floor construction and coverings. However, I believe it is safe to assume—again basing the assumption on the results of a great many installations involving all types of floor construction and coverings—that just about any of the common materials can be used.

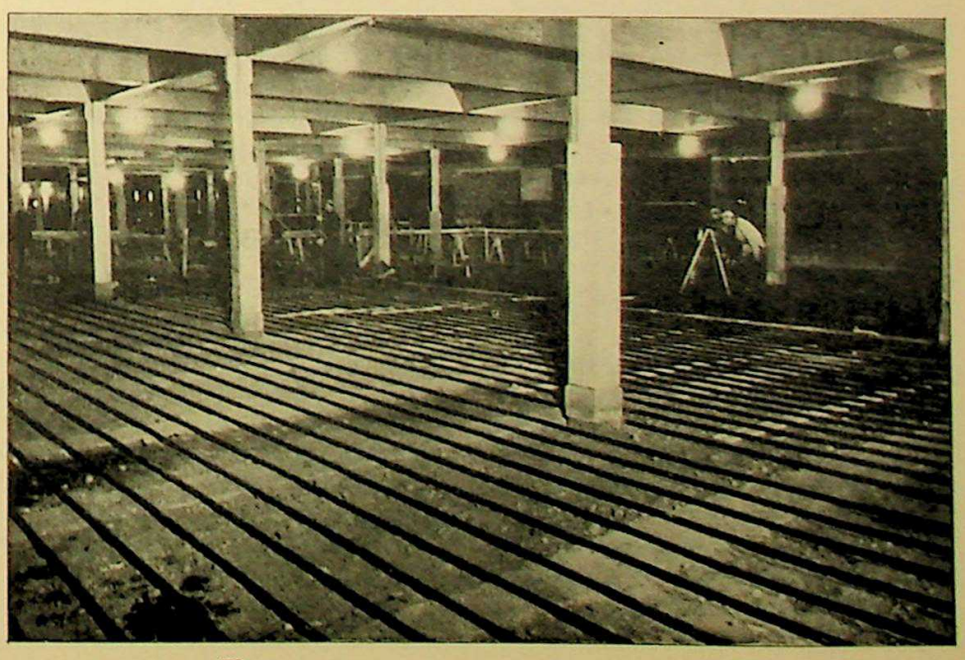
The matter of insulation is one which should receive just as much attention in a building having a radiant system as is given to the same problem when a conventional heating system is used. There is no economic justification for heating large portions of the great outdoors. Thus, a few dollars' worth of insulating materials really constitutes an ounce of prevention and will usually result in a more contented user.

Temperature Control

A somewhat unlooked-for characteristic of radiant heated space is that air temperatures closely follow the mean radiant temperature. This means that the ordinary room thermostat will provide a thoroughly suitable means of control. In most systems, thermostats of this type are wired to the circulator and close observation adequately proves this control scheme to be satisfactory. As a matter of fact, control design in a radiant heating system is subject to exactly the same latitude that is available for the conventional forced hot water system. Such devices as boiler water aquastats, anticipating thermostats, mixing valves, etc., will add just as much to a radiant system as they will to any other but their use is no more necessary than is normally the case.



Heat losses were rather high in a few small closed-off outside rooms. To supplement output from the floor coils, wall coils were installed, as shown



A view down the long grids just before the concrete floor was poured for a large personnel building at another plant. Incidentally, this is one of the largest radiant heating installations in this country; approximately 20,000 ft of wrought iron pipe was used. After the floor was poured and dried a covering of asphalt tile was laid

THE EDITOR—

I have read with great interest the article on radiant heating, by Charles A. Hawk, Jr., published in the January HPAC. Although I thoroughly agree with Mr. Hawk that there is nothing intricate either in the methods of calculating or installing radiant heating systems, I cannot agree entirely with some of the statements he made.

1) *Venting of Pipe Coils*—Pipe coils on radiant heating systems, when employing hot water as the heating medium, should definitely be vented. Although actual experience has shown that many unvented systems will work satisfactorily, there is never any assurance of this since it depends so much on the type of workmanship by the installing mechanic, and this, we will all agree, is quite variable. Naturally, it is not necessary to install a vent on each and every pipe coil, as in most cases one common vent to which all coils are piped is quite easily installed, but the pipe coils on hot water radiant heating systems should be vented if only for reason of safety, because the cost for correcting any air pockets after the floors are finished is quite expensive.

2) *Floor Covering*—My experience has shown that there are a few of the commonly used floor coverings which are objectionable for use in connection with radiant heating systems using floor coils. In particular, rubber tile floor covering can create difficulty due to odors and disintegration.

3) *Controls*—I cannot agree at all with Mr. Hawk in his statement regarding controls. True, the controls, as used on an ordinary radiator job, will serve fairly well to some extent on radiant heating jobs. However, I believe that the occupant of a radiant heated space expects and needs better control than is commonly used on radiator and warm air jobs. My experience has shown that:

a) Constant heat at the right temperature in accordance with outside temperature must be supplied to the radiant heating coils. This is particularly true in sections of the country where wide outside temperature fluctuations occur.

b) It is quite possible, from my own observation, that on a clear, sunshiny day, the outside temperature will drop 30 to 40 deg, while the sun itself has still its effect on a building well insulated and with large glass areas. The circulator is stopped from the room temperature effect on the room thermostat. Then suddenly the sun will lose its effect. In this short interim of time the room temperature may drop only ½ deg or less (not enough to start the circulator). However, the floor surface temperature in some test installations dropped 2 to 3 deg. This resulted in a considerable lag of time before comfortable conditions were again obtained. This difficulty can definitely be overcome by a control supplying heat constantly in accordance with outside conditions. In addition such a control will put a more even load on the source of heat.

c) The circulator should not be operated from an ordinary room thermostat, but rather by a radiant heat comfortstat. After all, on a radiant heating job we are not concerned with the actual air temperature, so why control the heat supply according to room temperature?

On single zone jobs this radiant heat comfortstat should preferably be wired to the control mentioned under (b) and employed to reduce the temperature of the heat supply below the temperature required according to outside temperatures. Thus, the advantages of constant circulation can be maintained.—E. M. MITTENDORFF, vice-president and general manager, Sarcotherm Controls, Inc.

Prominent Contractor Sees Big Postwar Part for Radiant Heat

THE EDITOR—

The ever-increasing interest in radiant heating should be cause for serious thought in the heating industry.

Inasmuch as our very existence depends on radiant heat from the sun, it seems strange that this type of heating has received so little attention and development by the industry.

The answer must be that ever-recurring indictment of heating contractors being poor salesmen. They always seem to follow the lines of least resistance, and are quite generally willing to let others do their selling for them. So the manufacturer's salesman, having no particular specialties to sell in connection with 100 per cent radiant heating systems (other than boilers and controls) has been a great influence in directing the trend in the opposite direction.

It was only a few years ago that the American Society of Heating and Ventilating Engineers gave any attention to this subject, and this was due to the fact that up to that time the heating industry did not seem to take any interest in it. Also, the fact that some English patents seemed to require the payment of royalties on some types of radiant heating installations might have been a further deterrent to advancement of interest in such systems in this country.

The ASHVE Heating, Ventilating, Air Conditioning Guide has included considerable engineering data on radiant heating for several years and perhaps as a result of this there are now hundreds of such installations in the United States that are giving unusual satisfaction in comfort and economy. The trend in these installations seems to be toward the floor type heating panels.

It is my belief that with increased knowledge and experience the ceiling type panels will become more popular, for the following reasons:

1) Pipes embedded in the ground or concrete where any moisture is likely to occur, are subject to rapid exterior corrosion.

2) There is considerable heat loss into the ground.

3) Different types of floor coverings have a marked effect on the heat input, thus upsetting the heat balance in the structure, or requiring accurate knowledge by the designing engineer of the types of floor coverings to be used in each room before the installation is made. The many types of floor coverings available, or likely to become available, would require constant and extensive testing in order to enable the designing engineer properly to compute the heat input calculations.

4) On the other hand, the ceiling type of heating panels are subject to practically no ineffective heat loss. Exterior corrosion of the heating surface would not occur.

5) The rate of heat flow from the panels can be easily calculated.

6) Furniture would not interfere with the heat input or distribution, nor would it be subjected to constant temperatures above the room temperature.

From the standpoint of comfort no actual comparative tests seem to have been made, but I am inclined to believe that the ceiling panel system will prove the more satisfactory when ceiling heights are not abnormal.

The design of radiant heating systems seems to be surrounded with considerable mystery, and the fabrication and installation of the heating coils seems to present a very costly problem. These beliefs are only the result of lack of actual experience.

The Heating, Piping and Air Conditioning Contractors National Association is now preparing all necessary engineering data for all types of radiant heating systems. These data will be in simplified form and will be included in the book of standards distributed to HPACCNA members.

It is the hope that this information will remove much of the present sales resistance to radiant heating systems by placing contractors in a position to include radiant heating systems in their certified heating program.

It is my opinion that radiant heating systems will play a big part in postwar activities.—H. M. HART, president, L. H. Prentice Co.

THE EDITOR—

The discussion entitled Prominent Contractor Sees Big Postwar Part for Radiant Heat, by H. M. Hart, published in the February HPAC, was very interesting. From where we sit we find it a very easy matter to agree with the headline of Mr. Hart's article, but actual experience seems to be somewhat at variance with his conclusion that the ceiling type panel will become first choice.

Perhaps 95 per cent of all radiant heating installations in this country today are of the floor type, and this figure seems to be increasing steadily. Most designers seem to be tending away from the ceiling type installation, except for occasional unusual conditions, if for no other reason than that it is usually less expensive to install the floor type system. There are other considerations involved, but in order to keep the discussion orderly, suppose we refer to Mr. Hart's article point by point.

1) Perhaps one of the greatest stimulants for radiant heating has been the building designer's desire to place the lower surface of his structure directly on the ground. In the past such construction has presented the obstacle of a cold floor, which has been exceedingly difficult to lick in climates where winters are at all severe. By the use of floor type radiant heating this obstacle has been easily overcome and more and more planning is being done along this line.

This still leaves standing Mr. Hart's objection of corrosion. As a remedy, two things should be done. First, restrict the presence of moisture as much as possible by using a crushed stone or gravel fill and, if appreciable moisture is to be expected, supplement with a waterproofing element. Second, use only piping materials which have a proved, longtime performance record against corrosion from ground moisture. There has yet to come to our attention any record of failure from corrosion in many hundreds of wrought iron floor type systems which go back over a number of years.

2) Heat loss into the ground is a difficult point to pin down, but continuing research by a number of different parties seems to indicate that it is a very small consideration. Furthermore, present calculation practice on the part of most engineers places this loss at a figure somewhere between 10 and 30 per cent of the total of other losses in the structure. In a room heated by ceiling coils or by any other conventional heating system, loss into the ground has to be taken into consideration and this normally results in a figure of approximately the same magnitude as those given above.

3) Different types of floor coverings have no measurable effect on heat input of floor systems. They affect only the operating level of the system and this introduces inefficiency only in the shape of losses at the boiler. The temperature drop from supply to return is the same, regardless of the floor covering. Floor systems have been used under all of the common floor coverings with apparently identical results. It is usually not necessary to know in advance what type of floor covering is likely to be involved because a well designed system will normally embody from 50 to 100 deg leeway in boiler operation which can be used to compensate for a variation in floor coverings. Balance from room to room is obtained simply by means of a small balancing valve in each element.

4) Upward heat loss from ceiling panels is usually just as great if not greater than downward loss from floor panels. Actually, for most construction this point becomes largely a toss-up.

As to exterior corrosion of the heating surface, it so happens that one of the few systems we have ever heard of which failed from corrosion was a ceiling installation. Consequently, it cannot be blithely said that exterior corrosion is not a factor in any radiant heating system.

5) Calculation of heat flow from

any panel, be it floor, wall or ceiling, is six-of-one and a half-a-dozen of the other. As a matter of fact, basing the statement on some of Dr. Giesecke's work, reported in Heating, Piping & Air Conditioning for August 1940, the convection output from a floor panel is twice as much as that of a ceiling panel with equal panel and air temperatures.

6) From all practical observations it would seem that no conceivable amount of furniture has any particular effect on the performance of floor type radiant heating systems. A number of churches making use of floor type systems seem to perform identically with other structures, and it is hard to imagine a floor surface more completely masked than the floor of a church with solid, stationary wooden pew seats over perhaps 50 per cent of the floor area. Certainly as far as damage to furniture is concerned, temperatures involved are so low and so close to room air temperatures that there is no apparent reason for expecting any damage. Furniture in rooms heated by floor panel systems which have aged several years shows absolutely no signs of undue depreciation.

As to the question of sensible comfort obtained with either floor or ceiling type systems, there are a number of tests going on at the present time which may throw some light on the problem. However, observation of a great many systems of both types does not seem to produce any marked differential to choose from insofar as comfort alone is concerned. Thus, the economical factors which seem to favor the floor type system will probably remain as the governing influence.

The information that the Heating, Piping and Air Conditioning Contractors National Association is now preparing a simplified data book is good news indeed.—C. A. HAWK, JR., engineering service dept., A. M. Byers Co.

THE EDITOR—

The article on radiant heat by H. M. Hart on p. 73 of the February HPAC is a good, commonsense approach to the radiant heating problem. An added advantage of this system is its possible use for cooling in summer. A complete system of air conditioning should include means for circulating cleaned, fresh air. In winter moisture can be added, and in summer the air can be dried. Chemical dryers are available and may prove less cumbersome than other methods, especially for small installations. With dry air there will be no trouble from moisture on the ceiling or other cooling surface.

Radiant methods of cooling and heating minimize the shock to the persons entering, as they avoid drafts.

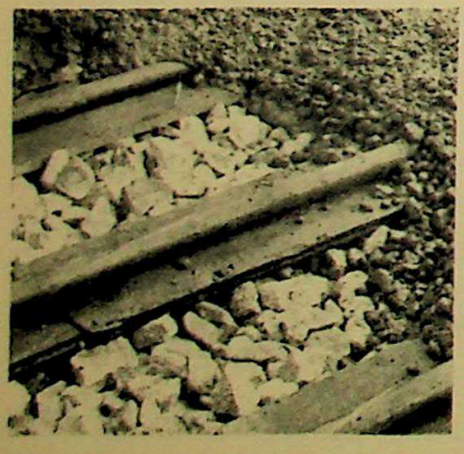
It is my feeling that the use of wrought iron pipes will materially reduce trouble from corrosion. When placed in the first floor ceiling they assist in heating the second floor area.

I am glad that the HPACCNA is preparing engineering data on radiant heating. I hope that they will send me a copy of it.—H. D. JAMES, consulting engineer.

FACTORY EMPLOYEES LIKE RADIANT HEAT

When the Murray Corp. decided to build an addition to its plant at Towson, Md., the main objective was to construct a modern factory with the use of a minimum amount of metals and other critical materials. A radiant heating system was installed in the addition.

Finished coils for the installation were laid on strips of 1 in. insulation board resting on a 6 in. crushed stone fill. The coils were then covered with a 6 in. topping of concrete. The concrete slab is the factory floor



An inspection made on one of the coldest days last winter, when the outside temperature was 10 F and a strong wind was blowing, showed the temperature in the addition, with radiant heating, to be 65½ F, and that it was "definitely comfortable" and there were "nc drafts."

The president of Murray Corp. half-jokingly reported that employees were competing with one another to be transferred to the new addition. He added that management and personnel alike were "sold" on radiant heating.

The radiant heating system consists of 2360 ft of 1¼ in. wrought iron pipe assembled into three "banks" of grid coils. Strips of 1 in. insulation board, 8 in. wide, were laid on the 6 in. crushed stone fill under each run of pipe. A 6 in. topping of concrete was then poured.

Several factors influenced Murray Corp. officials in deciding upon radiant heating for the plant addition. They wanted a concrete floor but were fearful of employee discomfort. Radiant heating suggested itself as a natural answer to this problem. Also, they wanted to utilize every inch of floor space.

Radiant heating is considered by many to be one of the major promises of the building industry for postwar housing as well as for commercial and industrial building.

Simplifying the Calculations for Exchange of Radiant Heat

B. F. Raber and F. W. Hutchinson Present Chart for the Graphical Solution of the Basic Radiation Equation

Because of the wide interest in radiant and panel heating methods, there has been considerable discussion in recent months of simplifying the calculations now necessary in solving problems of radiant exchange. The authors (who are professor of mechanical engineering and chairman of the department, and associate professor of mechanical engineering, respectively, at the University of California) have developed the method given here. The fundamental formula, equations for various cases, and an example showing the use of the method, together with tables of data on emissivity and shape factor, are presented with the graph

DETERMINATION OF the net radiant exchange between two surfaces separated by a non-absorbing medium is frequently both complex and tedious. The complexity arises from the need of evaluating the shape factor of one surface with respect to the other, while the tediousness is due to the need of working with the fourth power of the absolute temperature. The latter difficulty can be readily overcome, without loss in accuracy, by setting up a graphical solution of the basic radiation equation; the former difficulty cannot be avoided except through use of some form of approximation, but for a very large number of practical exchange problems such methods give results satisfactory within the limits of required engineering accuracy. The intent of this article is to present, in simple form, one approximate method of evaluating shape factors for the general case and to provide a graph obviating the need of any calculations in solving the basic equation.

The fundamental radiation formula, frequently called the Stefan-Boltzmann equation, is

$$Q_{sr} = 0.173\ F_s\ F_e \left[\left(\frac{T_s}{100} \right)^4 - \left(\frac{T_r}{100} \right)^4 \right] \quad \ldots\ldots[1]$$

where Q_{sr}=net radiant transfer from source to receiver, Btu per hr per sq ft of source; T_s, T_r=absolute temperature, F+460, of source and receiver respectively; and F_e, F_s=factors dependent on the relative emissivity and geometrical arrangement, respectively, of the surfaces between which radiant exchange is occurring. Strictly, the influence of emissivity and geometry cannot be separated into independent factors, but a combined term F_{es} should be used; in practice convenience dictates the separation.

The emissivity factor, F_e, can be expressed in terms of the emissivities, e_s and e_r, of the source and receiver. For most problems which commonly occur in practice, F_e can be evaluated by one of three equations, or can be estimated by interpolating between calculated values for two of the same three equations. These are:

Equation I: Where one surface, either source or receiver, is completely enclosed by the other surface and is small with respect to it,

$$F_e = \text{the emissivity of the enclosed surface} \quad \ldots\ldots[I]$$

Equation II: When one surface is completely enclosed by the other and both surfaces are of the same order of magnitude (a special example of this case occurs when the surfaces are infinite parallel planes.)

$$F_e = \frac{1}{\frac{1}{e_s} + \frac{1}{e_r} - 1} \quad \ldots\ldots[II]$$

Equation III: When neither surface encloses the other and the receiver intercepts only a small fraction of energy leaving the source,

$$F_e = e_s\ e_r \quad \ldots\ldots[III]$$

The shape factor, F_s, is numerically equal to the fraction of energy intercepted by the receiver of that leaving the source. Referring to Fig. 1 and considering that the areas A_s and A_r are in any position with respect to one another, it is possible to show that

$$F_s = \frac{1}{A_s} \iint \frac{\cos \phi_s\ dA_s\ dw}{\pi} \quad \ldots\ldots[2]$$

where dw is a small solid angle subtended by the infinitesimal area dA_r from a point on A_s.

But a solid angle is equal to the intercepting area projected on a plane normal to a line from the source divided by the length of that line squared,

$$dw = \frac{\cos \phi_r\ dA_r}{r^2} \quad \ldots\ldots[3]$$

or

$$F_s = \frac{1}{A_s} \iint \frac{\cos \phi_s \cos \phi_r\ dA_s\ dA_r}{\pi r^2}$$

Except in the simplest cases, equation 3 presents formidable difficulties in the numerical evaluation of shape factors. To avoid such difficulties and arrive at solutions which, though approximate, retain the rational method and in most practical problems are within the limit of permissible error, the integrations can be eliminated and the shape factor equation written in the form

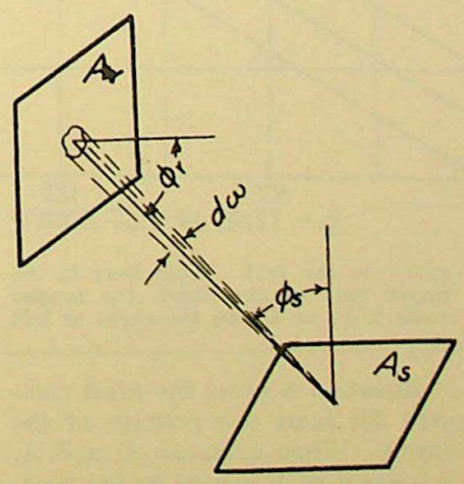


Fig. 1—Illustrating the geometry of the shape factor

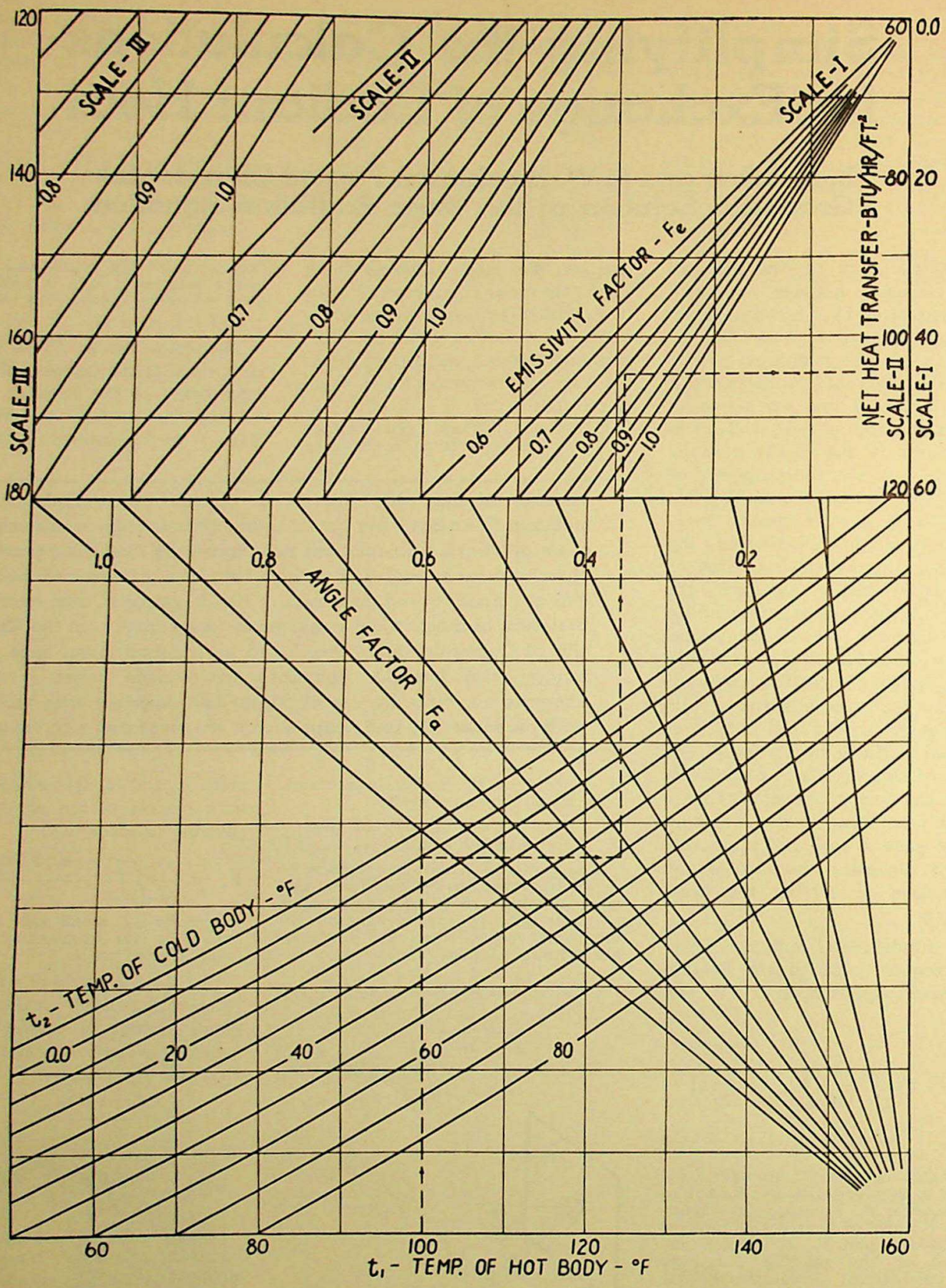


Fig. 2—Chart for graphical solution of the basic radiation equation. The dotted line refers to the example given in the text. Note that in the upper part of the chart, the proper scale I, II, or III on the right or left hand side should be used depending upon which of the diagonal emissivity factor lines in the top section is used

$$F_s = \left(\frac{\cos \phi_s'}{\pi}\right)(\cos \phi_r')\frac{A_r}{r^2}$$

$$= K_s K_r \frac{A_r}{r^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots [4]$$

Equation 4 gives the exact solution for some one position of the line r. When surfaces A_s and A_r are small with respect to the separating distance, values of ϕ_s', ϕ_r' and r do not vary greatly with position of r and hence the shape factor calculated by equation 4 has a value practically independent of the position of line r; for such cases

Table 1—Emissivities of typical building materials in temperature range from 0 F to 120 F

Material	e (average)
Clean metal plate (aluminum, copper, brass), average	0.10
Galvanized sheet iron (average condition)	0.25
Aluminum paint	0.50
Glass	0.80
Linoleum	0.85
Stone (average)	0.87
Wood (unpolished)	0.89
Brick	0.90
Paper	0.92
Plaster	0.95
Asbestos board	0.96

this equation affords a simple, practical means of directly evaluating the shape factor. Table 2 gives values of K_s and K_r for given values of ϕ. Note that in using the table, K_s is read opposite ϕ_s; K_r is read opposite ϕ_r.

Having determined F_e and F_a by the methods indicated above, the net radiant transfer in Btu per hr per sq ft can be obtained from Fig. 2 by entering the lower scale at the known hot body temperature, rising to intersect the line for the cold body temperature, moving horizontally to the intersection with the line for the known shape factor, rising to intersect the emissivity factor line, and moving either right or left to the intersection with the scale for net heat transfer.

Let us determine the heat loss by radiation from a small heating panel (plaster surface, operating at 100 F) located in a wall directly opposite an 8 sq ft window (inside surface temperature 0 F) in a room 20 ft wide.

Example Shows Use of Chart

Solution: For this case ϕ_s' and ϕ_r' have equal values approaching 0 deg, but since the areas are small with respect to the room width, the departure from 0 deg can be neglected; then, from Table 2 for $\phi_s' = 0$, $K_s = 0.3182$ and for $\phi_r' = 0$, $K_r = 1.0$. Therefore, from equation 4,

$$F_a = K_s K_r \frac{A_r}{r^2}$$

$$= 0.3182 \times 1 \times \frac{8}{20^2} = 0.00637$$

From Table 1, $e_s = 0.95$ and $e_r = 0.80$. From equation III, $F_e = e_s \times e_r = 0.95 \times 0.80 = 0.76$.

The solution of this problem is shown by the dotted line on Fig. 2. Since the factor F_a on the graph is 100 times that of the problem, the actual rate of energy transfer is 1/100 of the scale reading $= 0.01 \times 44 = 0.44$ Btu per hr per sq ft of panel.

If, in the above example, the heating panel were in the ceiling, the problem would be solved in the same manner, but ϕ_s' and ϕ_r' would not be equal either to zero or to one another.

Table 2—Source and receiver coefficients for use in the shape factor equation

$$F_a = K_s K_r \frac{A_r}{r^2}$$

Angle ϕ between normal to surface and connecting line, r	K_s	K_r
0	0.3182	1.0000
5	0.3170	0.9962
10	0.3133	0.9848
15	0.3071	0.9659
20	0.2990	0.9397
25	0.2883	0.9063
30	0.2755	0.8660
35	0.2606	0.8192
40	0.2438	0.7660
45	0.2250	0.7071
50	0.2046	0.6428
55	0.1824	0.5736
60	0.1590	0.5000
65	0.1345	0.4226
70	0.1089	0.3420
75	0.0822	0.2588
80	0.0552	0.1736
85	0.0277	0.0872
90	0.0000	0.0000

In certain special cases F_a can be obtained by observation rather than by calculation from equation 4. Whenever one surface is completely enclosed by another (as for the conditions of equations I and II), the shape factor is equal to unity if the source is enclosed, or equal to A_r/A_s if the receiver is enclosed; other similar examples (as parallel planes, concentric cylinders, etc.) will be readily apparent.

Letter from England

Leslie Rayner Writes of Tests on a Method of Floor Heating

LONDON, ENGLAND

PANEL HEATING with hot water has been very widely used in England and all possible dispositions of panels have been tried. The ceiling has been the most favored position as being almost free from the possibility of obscuration of the radiant heat. This ceiling heating is admirable in multi-story buildings where heat leakage upward through floors provides a measure of floor heating. But in single story buildings, it has been found that ceiling panels do not always produce comfortable conditions in that there is a possibility of cold feet. A great deal depends upon the floor construction. It has been found that there are single story buildings in which the occupants sit at desks where cold feet will definitely result with overhead radiant heating; examples of such buildings are schools and post offices.

A considerable number of English schools have been fitted with floor heating and three main types have been employed. The first installations were carried out with 2 in. diameter pipes, run in brick ducts formed under the floor slabs. In some cases the ducts were filled with sand. The construction was expensive and the heating in some cases uneven, although the cause was often bad design.

A number of buildings have been equipped with pipe panels embedded in floors. These function perfectly satisfactorily but have the disadvantage of requiring rather low water temperatures. Many schools and similar buildings are lightly constructed and need large quantities of ventilating air which is supplied direct from outdoors through windows. In such cases it has often been impossible to supply enough heat to the rooms by floor heating without reaching surface temperatures much too high for comfort.

For various reasons it may be desired to confine floor heating to parts only of the building. A logical choice for the remainder is hot water radiators and these may also serve as supplementary heating in floor heated rooms. Immediately there arises the necessity for hot water at two different temperatures which increases complication in the boiler house. In addition, two flow mains are required throughout the building although a common return main is permissible.

It is thus apparent that a method which enables hot water at normal temperatures to be circulated has advantages. The third type of floor heating was developed by the makers of a floor of sawdust-concrete composition, which forms a splendid covering for this type of heating.

The main feature of the installation is a heater of "dumb-bell" section having waterways top and bottom approximately 1 in. in internal diameter. The heaters are made in steel of any length up to 28 ft. The web connecting the top and bottom waterways is hollow so that the whole surface is water backed.

The floor is carried on concrete sleepers and the heater units are inserted in the ducts so formed. Insulation is applied to the bottom of the ducts to reduce, so far as is possible, heat losses to the ground. Strips of insulation laid along the tops of the heater units prevent local hot spots on the floor surface.

The floor is constructed by laying concrete panelled slabs across the tops of the sleepers. These are followed by a cement and sand screed into which the floor blocks are set. Flow and return mains are usually run along either side of the room. If access to the pipes is desired the flooring at the side of the room is fixed in trays carried on bearers. The finished floor level is about 12½ in. above site concrete.

In order to compare this type of floor heating with heating by hot water radiators, tests were run in specially constructed buildings. There were two rooms identical in dimensions and materials; the construction was 4 in. wood framing, sheathed with 24 ga corrugated steel outside, and lined with ½ in. insulation board inside. The roof was of galvanized steel with an insulation board ceiling. Floor construction was solid concrete in the radiator equipped structure.

Room "A" was equipped with the special heating elements described above. The total surface area of the elements was 159.8 sq ft. Standard radiators were used in "B," their heating surface plus that of exposed piping being also 159.8 sq ft. Underfloor mains and connections had equal heating surface in both cases.

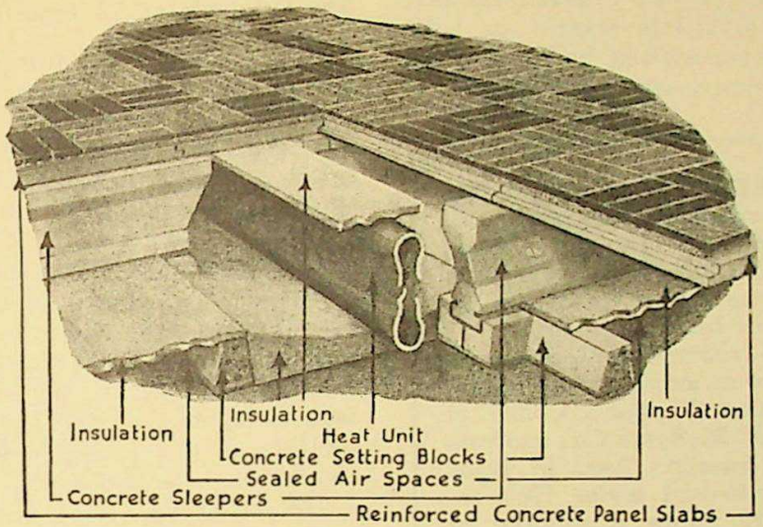
The elements and radiators were supplied with hot water from individual cylinders, each of which was fitted with electric immersion heaters. Water flow temperature was regulated by a thermostat at the top of each cylinder controlling the immersion heaters. Energy input to each room was read on a standard meter. All circulating pipes were insulated.

Temperatures were measured by mercury in glass thermometers.

FLOOR HEATING

Low temperature radiant heating has been widely used in England, and practically every possible disposition of the panel heating surfaces has been employed. One scheme, developed by the makers of a floor construction, involves use of heating surfaces of "dumb-bell" cross section through which hot water is circulated. This heating surface is installed in duct spaces in the floor. With a mean water temperature of 160 F, the air temperature in the subfloor is 100 to 110 F and the surface temperature of the floor is around 75 F. Heat emission is about 300 Btu per lineal foot of the "dumb-bell" surface, about 270 Btu of which reaches the room. . . . Mr. Rayner gives here some test results on two identical rooms, one heated by the method described and the other heated by conventional hot water radiators

The results are therefore not without objection since these instruments do not register equivalent thermal conditions. It would have been better to use a eupatheoscope and record the test results on the equivalent temperature scale. It is probable that the equivalent temperature may be accepted as approximately equal to the air temperature for radiator heating but in the case of floor heating, the equivalent temperature will range 2 to 5 F higher than the air temperature.



Hot water is circulated through the "dumb-bell" sections installed in ducts in the floor construction

The first test illustrated the time lag inevitably introduced by the necessity to warm the mass of floor before floor heating becomes effective. Heat input was controlled by room thermostats. The rooms were left unheated for 16 days in severe winter weather. Using the temperature at the 3 ft level as an approximate index of comfort, it was found that the radiator heated room was comfortable 6 hr after the commencement of the test, while 12 hr was needed to attain comfort conditions in the floor heated room. The test was run for 168 hr, when it was found that the heat inputs had been 3,969,240 Btu for radiator heating and 3,229,270 Btu for floor heating, showing a saving of 18½ per cent in favor of floor heating. It may be objected that room "B" was usable 6 hr earlier than room "A" but this objection is invalid, for the thermal capacity of the floor would enable room "A" to be used for some hours after room "B" was too cool for comfort.

The second test was indicative of the results to be expected with continuous heating. The rooms were brought up to the same temperature and the room thermostats set to cut in at 58 F and out at 60 F. The test was run for 60 hr and the results showed that floor heating required less heat input, the saving being about 10 per cent.

The third test was indicative of results to be obtained in practice when heating is shut off at night. Both rooms were kept at constant temperature for two days, heat being cut off at 4 p.m. on the day prior to the test. Heat was put on at 8 a.m. on the test day and cut off again at 4 p.m. The salient feature of the test result was the slow cooling of room "A," the temperature at the 3 ft level dropping 4 F in 4 hr. The reduction in energy consumption for floor heating was about 7 per cent in this case.

Windows were kept shut during the experiments and it may be assumed that infiltration would be of the same order in both rooms. Room "A" had a slightly more severe exposure than room "B."

Measurements have been made of the heat output of the unit and it is found that with a mean water temperature of 160 F, the emission is about 300 Btu per hr per lineal ft. This results in an air temperature in the subfloor of about 100 to 110 F. The surface temperature of the floor is then 75 F. Of the 300 Btu emission, about 270 Btu reaches the room. The latter figure is used for design purposes to ascertain the total length of unit to be installed. Heat losses for design are computed in the normal way.

Corrosion of Pipe In Radiant Heating

THE EDITOR—

There has been some discussion of late concerning the corrosion of pipe used in radiant heating installations buried in concrete floors. Reference is made to p. 137 of the March HPAC.

If care is taken to see that the pipe is completely surrounded by well proportioned and well mixed concrete there would be very little danger of corrosion, because the concrete will protect the pipe.—R. C. FARIS, engineer, The Equitable Powder Mfg. Co.

What's This Radiant Heating?

WHAT ARE THE specifications for the "perfect" heating system? While each person is privileged to stress one of a number of essential characteristics of the perfect system, there is substantial agreement that heating plant performance should follow some such ideal pattern as this:

1) Provide maximum human comfort.
2) Be automatic.
3) Be completely concealed.
4) Reduce air currents to a minimum.
5) Be clean.
6) Concentrate warmth where it is needed most—at the floor level.
7) Be competitive in original cost.
8) Be economical in fuel consumption and maintenance.

Radiant heating comes very close to meeting these specifications. The record of its performance has been attested by the occupants or owners of more than a thousand structures in this country where the system has been functioning for from one to 35 years.

Radiant heating is not a new method. The wealthy Romans heated their homes by building a fire in the basement and letting the gases and smoke rise to the floor, over to hollow walls, and up through the roof. There are evidences of radiant heating in England left by the Romans after their occupation of that country. The English engineers picked it up some 50 years ago and started experimenting with the idea. One of them invented a cast panel that he could hook up in series to meet his heat requirements. This is where the name "panel heating" comes from.

The oldest radiant heating job I know about in this country is one installed about 35 years ago in what is now Gary, Ind. At that time the village of Glen Park built a four room school, two stories high. The architect ran his heating pipes between the wood joists and produced such comfortable conditions that when the village was later incorporated into Gary, the teachers in the city schools vied with one another to teach in that school. The superintendent came to the conclusion that that would be the ideal way to heat schools.

Fireproof schools then came to the front but nobody seemed to know how to run the pipes in concrete; therefore, the idea was dropped. It was not until seven or eight years ago that any large scale use of this type of heating was started in this country. The cause for this revived interest was that some architects wanted to build structures without basements, and their experiences had taught them that concrete floors on the ground were hard to keep warm.

THAT'S A question almost anyone in the heating business is likely to have tossed at him these days, for there is a tremendous general interest in heating methods . . . and "radiant heating" comes in for no small part of this attention. George B. Coffey, of the A. M. Byers Co., answers the question here in brief, easy-to-read style. He's recently made a number of talks on the subject before various engineering and contractor groups, so his comments cover several of the questions which have come up at these meetings. You'll find this quick summary helpful when you're asked "What's this radiant heating?"

Almost everyone has had some experience with radiant heating, even if in crude and uncontrolled forms. For instance, you may have tried to warm the tile floor in your bathroom by placing hot water pipes under it, or by increasing the radiation from your fireplace by putting a reflector in back of the fire basket:

I know an architect who put a stainless steel sheet in the back of his fireplace. He had no method of measuring the increased heat that radiated into the room except that Fritzie, their dachshund, who formerly lay at the edge of the hearth, moved back about 10 ft. His conclusion was that because the dog moved 2½ times farther back, the radiation into the room had been increased by that amount.

Another instance would be that of the room directly over the boiler or furnace in a home. It is always the most comfortable room when cold weather arrives because the floor is warm and occupants have the benefit from the radiant rays emitted from that floor.

The Principle of Radiant Heating

Let us consider the principle of heating by radiant energy. The basic principle behind it is that if you take a heated object and a cold object and place them opposite one another, the heated one will lose heat to the colder one. This action will take place as long as the heated object can "see" the colder one, or just as long as a straight line can be drawn from the surface of one to the other. The rate of heat loss depends upon the size and temperature of the heated object in relation to the cold object.

Radiant energy leaves the hot surface in waves much as light leaves an electric bulb. These waves strike the colder surface and some are absorbed, while others are reflected to other cold surfaces. Those that are absorbed heat that surface, which in turn re-radiates its heat to the objects that are colder.

What is the reaction of the human body to such heating? We all have been told that the human body needs no external heat for its own comfort, that it manufactures its own heat even to the point of a surplus of some 400 Btu per hr. To be comfortable, then, we must get rid of that much heat every hour. The average body will lose about 50 per cent of that amount by radiation; the remainder is lost by convection and evaporation. This explains the paradox of the "cold 70" temperature with which everyone has had experience. In this case, the body is losing its heat by radiation to cold walls and objects faster than it can afford; therefore, it feels chilled. If we control the radiant heat loss from the body, then the air temperature becomes virtually insignificant. This is a fresh approach to achieving human comfort. Radiant heating does precisely that.

The object of a radiant heating system is to warm a large room surface of sufficient size to give ample radiant energy for the room. This can and has been done in various ways. However, a majority of designers have elected to do it with wrought iron pipe coils imbedded in the floor or ceiling through which hot water is circulated. The majority of designers have elected to use floor coils instead of ceiling coils primarily because of simplicity and economy in installing. A ceiling coil will work just as well as a floor coil. Side wall coils are used only as auxiliaries to either of the other two.

Conventional Equipment Used

The same boilers, controls, circulators, and other equipment are used in radiant heating installations that are used in forced hot water systems. Some control manufacturers produce a eupatheoscope type of instrument that is operated by radiant energy waves. This is a black bulb instrument which absorbs the rays and, upon reaching a predetermined temperature, shuts the system off.

However, very good results are being obtained by the use of common air temperature thermostats, because the average temperature of the room surfaces and the air temperatures will closely follow each other. Lower thermostat settings are consistently very comfortable in radiant heated space. Occupants report 62 to 68 F as "very suitable."

The installation cost of a radiant heating system, from all the figures we have been able to accumulate, is about the same as that for a good forced water system, averaging from 6 to 9 per cent of the total cost of the project.

From composite records available on operating costs, savings in fuel consumption of from 15 to 30 per cent with radiant heating systems are common, and the bulk of them seem to be closer to the 30 per cent mark. The surface of the skin has a temperature of approximately 83 F, so the maximum floor surface temperature in a floor installation is held near that temperature. An 85 F floor does not give the hand, when placed on it, any sensation of heat or cold. This is, of course, the maximum temperature —the one for zero weather. In milder weather the floor temperature is somewhat lower.

Floor coverings, it has been determined, have little effect on the system. If anything, reports point to an improved comfort condition with carpeting on the floor, the theory being that each wool fiber acts as a fin for a jumping off place for the heat waves, whereas a smooth floor does not have these "springboards."

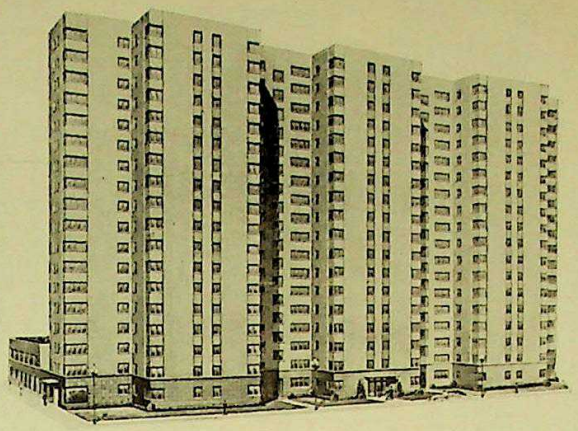
Any competent heating engineer can very easily design and lay out a radiant heating installation that will produce comfort. By using the pipe coils, we have a different technique in heating and we have

The author shows how floor coils for radiant heating are installed

opened a new field of exploration for the technicians. Some of their reports have a tendency to confuse the average person to the point that he is afraid to try radiant heating. To illustrate, you and I do not care what happens when we turn on the radio as long as we get clear reception of the program selected. It is the same with radiant heating. I have seen jobs that apparently have had no rhyme or reason to their design and yet they are producing comfortable conditions. With only a slight bit of engineering they would probably be more efficient in operation but no more comfortable. The point to remember is that the system operates at medium water temperatures, and by merely raising or lowering that temperature a few degrees almost any design errors may be corrected.

Snow Melting

As a byproduct of this type of heating there has been mounting activity in using this construction for melting of snow from thoroughfares. Several industrial concerns have placed hot water pipes in the walkways and open truck ramps around their plants, and similar installations have been made under driveways at private residences. It seems altogether possible that this application may become commonplace in the northern part of this country after the war—at filling stations, freight and passenger depots, transportation terminals, beneath the runways at airports, even under the sidewalks in downtown areas.



The Grosvenor House apartment building as it will appear when completed this fall. The panel heating system will also provide panel cooling by means of city water in summertime (photo courtesy Earl W. Morrison, architect)

Big Grosvenor House Apartment Has Panel Heating and Cooling

ERWIN L. WEBER, consulting engineer, describes the 18 story Grosvenor House apartment building under construction in Seattle—believed to be the largest FHA insured mortgage apartment house and to have the largest panel heating and cooling installation in the U. S. The coils for the heating were shop fabricated on practically a mass production basis, leading to important economies, and the cost of labor for installation was extremely low, according to Mr. Weber

GROSVENOR HOUSE—now being completed by Harfst & Henson for the Kellerblock Corp. of Seattle—will be the largest FHA insured mortgage apartment house under one roof. It will be 18 stories high, with 22 apartments on each typical floor, a total of 370 apartments facing Wall St., and a three story garage with roof garden facing Vine St. There will be 12 stores on 5th Ave. and a restaurant and eight stores on 6th Ave.

The boiler plant comprises two steel hot water boilers, each of 10,200,000 Btu rating, arranged for rear oil firing and readily convertible to front coal firing. The oil storage tank is of 8500 bbl capacity. Coal and ash bunkers are provided.

The hot water tank has 3360 gal capacity and has a copper heating element with 600 sq ft of surface.

Three Converters for Heating System

There are three converters for the heating system, as follows:

L—for low temperature floor coils, with 100 sq ft of heating surface.

S—for south exposure apartments, with 200 sq ft surface.

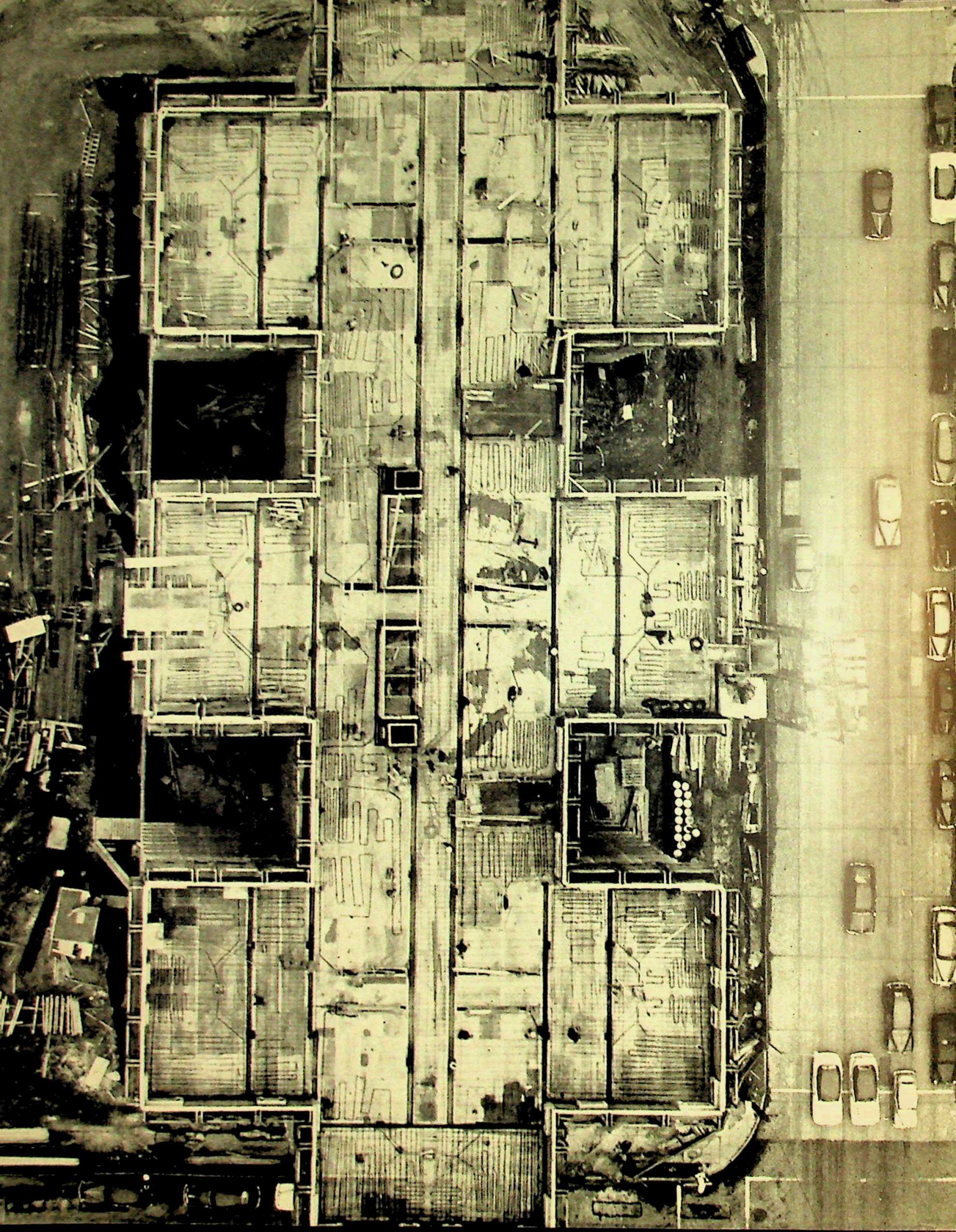
N—for north exposure apartments, with 400 sq ft surface.

Duplicate motor driven centrifugal pumps are provided for the boilers, domestic hot water circulation, floor coils, north coils and south coils.

The "environditioning system" has about 35 miles of steel pipe imbedded in the concrete ceiling slabs and first floor ground slab of the building, making it the largest panel heating and cooling system in the United States. A concealed shutoff valve is provided for each room. The heating and cooling system is completely concealed.

The thermostatic control systems are operated by outdoor thermostats which vary the water temperature according to outdoor temperatures. In the floor heating coil system, the water temperature will vary from 75 to 105 F with outdoor temperatures from 65 to 20 F.

In the north and south ceiling coil systems, the water temperature will vary from 75 to 125 F with outdoor temperatures from 65 to 20 F. The water temperature will be increased ½ deg for each mile of wind



Aerial view *(opposite)* of the 17th floor of Grosvenor House taken at an altitude of 600 ft and showing the radiant heating coils. The 18 story building is 230 ft long by 100 ft wide, and there is a three story garage of the same dimensions in the rear (photo courtesy Bethlehem Pacific Coast Steel Corp.)

velocity in excess of 15 mph.

The wind adjusting control is a combination of a weathervane with typical rotating arrow and a standard static pressure control. The static pressure control sensing the pressure as exerted by the velocity of the wind, readjusts the thermostat in the flow line to the building and through increments of control air pressure readjusts the water temperature controller above its setting as made by the temperature outside controller. The increment in water temperature in proportion to wind velocity is accomplished through the proper setting of the static pressure regulator.

Solar Heat Control for South System

The south system will also be provided with a solar intensity mechanism which will immediately shut off the heating on the south apartments when the sunshine gets to a predetermined intensity, to counteract the solar heating effect therefrom.

The solar compensator is an insulated enclosure with a window in one side and is mounted so that its window is parallel to the windows in the zone it serves. The temperature inside of the solar compensator is equal to the outdoor temperature plus a temperature rise which is proportional to the solar energy received. The setting of this instrument is such that at a certain temperature as indicated by the combination of outdoor temperature and solar energy all heat addition to that zone will be immediately stopped.

All pumps are controlled by clocks to turn the various systems on and off at predetermined times.

Exhaust registers with boots are provided for each bathroom and kitchen, and are connected with a 36,000 cfm exhaust fan in the penthouse. Individual exhaust fans are provided for the garage, transformer vault and restaurant.

The heating coils will be used for panel cooling in the summer by circulating city water.

Cooling water will be run through the coils and pass out of the overflow line to be discharged through spray heads on the roof to counteract the solar radiation to the roof and keep the attic space and top (18th) floor cool.

Another unique feature of the building is that the cold water system is arranged for continuous circulation. This avoids the tepid cold water often found in apartments.

Each apartment has a built-in sink, wall outlet water closet with flush valve, lavatory and bathtub with shower and shower curtain. Each apartment is provided with electric range and refrigerator, soft lighting fixtures, and with door chimes. There are four electric elevators. All hall lights are wired on continuous three-way circuits. Each apartment is metered.

All flow and return risers were run in the interior plumbing stack spaces, thus eliminating the cost of additional chases and furred in spaces in the outside walls, and materially decreasing the number of risers.

System Economical to Install

The heating system showed many remarkable economies in its installation. The cost of the coils was under 11 cents per lineal foot, completely bent, welded, tested and delivered at the site. About 5 lineal feet of coil is the equivalent of 1 sq ft of equivalent direct radiation.

The riser system installation was very economical because of the comparatively few risers which were located in the inside plumbing shafts instead of at the outside walls. These shafts also provide an excellent place to install and conceal expansion loops in the risers.

From the downfeed flow risers, the flow branch for each apartment is taken off and then extends around near the outside wall. The coils for the individual rooms are taken off and a return line for each room is run to the kitchen, where it is provided with a radiator valve at the ceiling of the broom closet and connected through a short header to the return risers.

Only 20 coil patterns were required for the entire apartment heating installation. The coils, flow mains, return mains and headers were shop fabricated on practically a mass production basis. They were then assembled on the form deck, all connections field welded in place, and tested with water at 125 psi.

The cost of labor for installation was extremely low. The heating contractor was allowed only one day per floor to install and field weld the coils. Six welders performed this work in less than a day, making the labor per floor six man-days.

Aerial Photo Shows Coil Installation

The accompanying aerial photograph was taken at 11:00 a.m. The coils were first welded and tested at the left end of the building. During this time the reinforcing steel and conduits were placed in the corridors and halls. It will be noted that at 11:00 a.m., reinforcing steel and conduits are already in place in the three wings at the left. One welding crew is working in the lower center wing and another in the right top wing. They were finished at 2:30 p.m. On the following day, all reinforcing steel and conduits were in place and concrete pouring was begun at the left end of the building.

Solves Temporary Heat Problem

Radiant heating quite effectively solves the temporary problem of heating during construction. In the recently completed Yakima municipal airport, the coils were filled with brine last winter when the outdoor temperature was 10 F and the interior finishing of the building was completed during the most severe winter experienced in that region.

The cost of the installation at Grosvenor House compares very favorably with other methods of heating such structures, in the author's experience.

The building was designed by Earl W. Morrison, architect. W. H. Witt Co. were the structural engineers. The electrical, mechanical and sanitary equipment was designed by the author. The heating, ventilating, sprinkler and plumbing systems are being installed by the University Plumbing and Heating Co.